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NUCLEAR WEAPON EFFECTS UNCERTAINTIES IN TACTICAL WARFARE

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

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Final Report for Period 2 June 1975—3 November 1975

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The study identifies important uncertainties in regard to tactical nuclear warfare, devises methods for collecting battlefield data on these uncertainties, and proposes plans and procedures for collecting, evaluating, and disseminating the data to important users.

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SUMMARY

This research identifies the uncertain major nuclear effects and assesses the feasibility of collecting data on a tactical nuclear battlefield to assist in clarifying these uncertainties. Where collection was feasible, we evaluated the immediate and near-term operational benefits of reducing the uncertainty. For uncertainties that passed both tests (data collection feasibility and operational benefit), we devised plans for collecting the data, analyzing it, and disseminating the analysis to users.

From discussions with Science Application Inc., who are planning for underground testing, and with Stanford Research Institute, who are planning for test readiness, the major uncertainties are:

- Effects of low airburst precursor.
- Effects of blast and ground shock from surface and shallow underground bursts.
- Effects of combined thermal and blast effects on equipment.
- Effects of dust clouds on communications and radar.
- Volume of fireball causing interference to radar and communications.
- Correlations among visible blast damage, casualties, and equipment damage.
- Human response versus time as a function of radiation dose.

- Effects of multiple injuries (blast, thermal, and radiation).
- Radiation from vent stem from shallow to deep subsurface bursts.
- Adequacy of fallout prediction system.
- Loss of effectiveness of U.S. units by type as a function of percentage of casualties.*
- Same for enemy units.

A. Wars Involving U.S. Forces

We investigated the means that are likely to be available for collecting nuclear effects data in a tactical nuclear environment involving U.S. forces. This investigation was based on current organization and plans. We then analyzed (Section III) each of the listed effects uncertainties to determine:

- The data required to dispell or reduce the uncertainty.
- The feasibility of collecting the data.
- The immediate operational benefits of dispelling the uncertainty.

In six cases, it was judged feasible to collect the necessary data. There also appeared to be a significant immediate operational benefit from reducing the uncertainty involved. These were to:

- Develop human response versus time as a function of radiation dose.

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*Percent casualties that would prevent mission performance.

- Determine effects of multiple injuries to personnel.

- Determine loss of effectiveness of U.S. units as a function of casualties.

- Determine adequacy of current fallout prediction system.

- Determine combined thermal and blast effects on aircraft.

- Determine loss of effectiveness of enemy units as a function of casualties.

Collection of data on these uncertainties requires the following positive actions:

- Issue gamma neutron dosimeters which will cover the dose range of interest to selected troops (e.g., every third or fourth man). A small inexpensive type is described in Section III.

- Provide selected NBC personnel at all echelons with concise questionnaires so that, if the situation permitted, they could be sent to interrogate survivors of U.S. units who had suffered high radiation doses and/or multiple injuries.

  Develop report procedures from division and/or brigade TOCs to corps CBRE of casualties sustained, equipment lost, and recent experiences for units declared combat ineffective.

  Develop division CBRC report procedures to corps CBRE for cases where significant fallout occurred outside of the predicted danger areas.

- Instrument aircraft with plastic or paint strip that will indicate thermal exposure by change of color and with deformation type pressure gauge that will record integrated pressure.

* Develop a list of special items to be observed and reported by units attacking enemy forces supported by nuclear fires. These will pertain to enemy units becoming ineffective.

* Develop special questions for POW interrogators that will seek to determine casualties and damage sustained by enemy units that become combat ineffective.

* Prepare fill-in-the-blank type messages directing changes in the service weapons employment manuals (e.g., Army Field Manual 101-31), which could be dispatched to all units in the event findings regarding effects uncertainties required a change in employment planning or procedures.

It would be advantageous to have the collected data analyzed at the Corps CBRE, since they are moderately close to the data sources; this would also provide redundancy (there are currently two U.S. corps in Europe). An exception is that data relating to the vulnerability of USAF aircraft should be analyzed at the Direct Air Support Center (DASC). Findings on most uncertainties should be cross-checked among corps CBREs and with Army CBRE and, if they appear valid, should be disseminated via the preplanned messages to all TOCs, DASCs, and FSCCs involved in nuclear planning or targeting. Any findings on aircraft vulnerability to combined blast and thermal effects should also be reported to all USAF and Army units operating, controlling, or requesting aircraft.

B. Wars Involving Non-U.S. Forces

Sections II, III, and IV of this report cover wars involving U.S. forces. Section V covers wars in which the United States is not involved. In the latter investigation we assume (1) that a

tactical nuclear war has been concluded between two (or more) lesser nuclear powers and (2) that the United States has been allowed to send a team of observers to that nuclear arena. The question is "What could the U.S. team learn about the uncertainties that would be of significant benefit?"

Collection of data on many of them would require instrumentation that would probably not be present on foreign battlefields. In cases where the United States is providing military assistance to potential participants, it might be possible to incorporate some instrumentation in the equipment being furnished.

However, even with no instrumentation some useful observations could be made:

- Medical officers might provide data on the frequency of combined blast and burn injury and on the typical casualty rates. By the time the U.S. team arrived on the scene, some symptoms of radiation would probably have been diagnosed, giving approximate received doses; hence, there might be some data on the frequency of total combined injury.
- Discussions with operational commanders and staff could provide data on the loss of unit effectiveness as a function of percentage of casualties.
- If the battlefield had not been policed and if a collaborating former participant would disclose where specific yields had been used, it might be possible to reconstruct the scene and glean useful data on the vulnerability of certain equipment to blast. Even without collaboration, an analysis of residual neutron induced radiation could provide an estimate of weapon yield and ground zero (GZ).

Prior planning would be most important in attempting to collect information from someone else's war. Hence, a study should be made to examine:

- The likely areas of occurrence and differing degrees of cooperation that U.S. personnel might encounter.
- The key personnel who should be questioned, their attitudes toward the United States, and the questions to be asked.
- The number of observers desired, their qualifications, and the required training.
- The instruments and other equipment needed and requirements for stockpiling.

PREFACE

This research was performed to identify important uncertainties in tactical nuclear warfare, to devise methods for collecting battlefield data on these uncertainties and to propose plans and procedures for collecting, evaluating and disseminating the data to important users. The work was a scoping effort which has provided some insights that should stimulate thoughts in this area. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either express or implied, of the Defense Nuclear Agency or the U. S. Government.

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I INTRODUCTION

This research identifies the important effects of nuclear uncertainties, to assess the feasibility of collecting battlefield data that would clarify or dispel those uncertainties, and where collection of data from the battlefield was possible and there were significant benefits, to devise plans for collecting, evaluating, and disseminating the data. Emphasis was placed on cases where increased knowledge would result in more effective weapon employment with the time span of a very short war.

It was assumed that any interference with the combat effort would be prohibited, that data collection would require a minimum of additional equipment, if any, and that the resources devoted to this effort would be austere.

The original concept was to collect data on a U.S. battlefield. However, at the client's suggestion, a supplemental concept was added--that of what could be learned by a team of U.S. observers visiting the scene of a tactical nuclear war or battle that did not involve U.S. forces.

II EFFECTS DATA AVAILABLE FROM CURRENTLY PLANNED SYSTEMS

A principal source of burst data (location and yield) will be the Nuclear-Biological-Chemical (NBC) reports.[1*] The system based on these reports is completely dependent on human observations made with instruments that are usually present on the battlefield (e.g., aiming circles and compasses). In Appendix A, we present an analysis of the inaccuracies that might be expected from this system. Except when there is a visible crater, the errors in the location of ground zero (GZ) can be on the order of from 100 to 400 meters.[†]

Height of burst (HOB) will be largely unknown--reporting procedures distinguish primarily between air and surface bursts. If the estimated yield is based on measurement of cloud diameter, the error can be on the order of ±50%. If based only on cloud stabilization altitude, one sigma accuracy will be about +120%, -70%.

The army is developing an automatic nuclear burst detection system (NBDS).[2] Conceivably such a system could provide burst data (GZ, HOB, and yield) with sufficient accuracy to dispel certain

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*References are listed at the end of the report.

†By a detailed survey of neutron-induced radiation, or by careful photo interpretation, GZ could be located to within 50 to 100 meters. However, the basic approach in this study is to see what could be learned and used quickly. This concept does not permit prolonged, costly redigestion of data.

effects uncertainties (e.g., precursor effects). To avoid classification of this report, the specified accuracies for burst data from the NBDS are not given. However, these location accuracies will not be a substantial improvement over those that might be possible with the manual (NBC) system now in use.

The Army has radiac instruments and is developing improved ones for monitoring fallout. The issue is generally six to eight for company-sized units. These instruments can be used for static monitoring or for making radiological surveys. Hence, there is (and will be) a capability for monitoring that will hopefully verify the accuracy of fallout predictions. There is also a fountain-pen-sized dosimeter that will measure received-radiation doses of up to 600 rad (tissue) gamma, either initial gamma radiation or fallout. The basis of issue is two per platoon. As is discussed later, 600 rad (tissue) gamma excludes important neutron radiation and does not cover the dose range needed to investigate radiation related effects uncertainties.

III EVALUATION OF THE FEASIBILITY OF DATA COLLECTION ON UNCERTAINTIES AND RESULTANT OPERATIONAL BENEFIT

In this section, we (1) list the data required to decrease uncertainties of effects, (2) evaluate the feasibility of collecting that data on the battlefield, and (3) assess the operational benefit of decreasing the uncertainty. Findings regarding uncertainties were considered to be of high operational benefit--if they could significantly change damage criteria.* The results of this evaluation are summarized on Table 1.

As was anticipated, in many cases we found that either it would not be feasible to collect data on the uncertainty or that, given the data, the tactical benefit would be small. To emphasize the positive aspects of the findings, the analyses of those uncertainties that might be decreased with definite tactical benefit are presented first.

A. Human Response Versus Time as a Function of Radiation Dose

The uncertainties about human response as a function of radiation dose relate to what dose will incapacitate a person in what time, the degree of incapacitation, and the time the person is

*Damage criteria specifies the level and type of damage that the planner seeks to inflict on a target.

TABLE 1. SUMMARY OF UNCERTAINTY ANALYSES

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UNCERTAINTIES	DATA REQUIRED	FEASIBILITY OF COLI
Human response versus time as a function of radiation dose.	Chronological description of impairment experienced by a number of men who have received a wide range of doses.	Feasible, providing troop with gamma neutron dosime
Effects of multiple injuries (blast, thermal, and radiation).	Chronological description of impairment experienced by a number of men who have suffered a range of mixes of multiple injuries.	Feasible, with same provi plus a survey team capabl ing degree of burns and n blast injuries.
Loss of effectiveness of U.S. units by type as a function of percentage of casualties.	Percentage of casualties and recent experience of U.S. units declared combat ineffective.	Feasible--data are availa and Div CPs.
Same for enemy units.	Same as for U.S. units above.	Feasibility is doubtful; important and some data a POW interrogation.
Combined thermal and blast effects on equipment.	Calories/cm^2, static and dynamic pressures, and damage.	Possibly feasible, with s mentation on selected equ
Adequacy of fallout prediction system.	Predicted pattern versus pattern actually experienced.	Feasible--CBRC does predi plots actual events from ports.
Low airburst precursor effects.	Burst data (x,y,z, and yield), static and dynamic pressures.	Not feasible--burst data pressures would require i battlefield.
Shock from surface and shallow underground bursts.	Burst data, velocities and accelerations.	Same as above.
Blast effects from surface and shallow underground bursts.	Same as for precursor effects.	Same as above
Effect of dust clouds on communications and radar.	Reports of interference in presence of dust clouds, type and frequency of equipment.	Feasible.
Fireball volume causing interference to radar and communications.	Measurements by radars of cluttered area, reports of interference in presence of fireball, type and frequency of equipment.	Feasible.
Correlation between visible blast damage, casualties, and equipment damage.	Counts of casualties, survivors, and equipment damage with associated distances from GZ to outer limit of visible damage.	Feasible; however, it wou significant manpower and error potential.
Radiation from vent stem from shallow to deep subsurface bursts.	Burst data and doses received at a number of points.	Feasible, assuming eithe luminescent dosimeters o issue dosimeter.

RTAINTY ANALYSES

TABLE 1. SUMMARY OF UNCERTAINTY ANALYSES

DATA REQUIRED	FEASIBILITY OF COLLECTION	OPERATIONAL BENEFIT
logical description of impairment enced by a number of men who have ed a wide range of doses.	Feasible, providing troops are equipped with gamma neutron dosimeters.	High--could cause significant change in damage (or targeting) criteria.
logical description of impairment enced by a number of men who have ed a range of mixes of multiple es.	Feasible, with same proviso as above plus a survey team capable of diagnosing degree of burns and nature of basic blast injuries.	High--same as above.
tage of casualties and recent ex- ce of U.S. units declared combat ctive.	Feasible--data are available at Bde and and Div CPs.	High--could significantly change targeting criteria.
s for U.S. units above.	Feasibility is doubtful; but answer is important and some data available from POW interrogation.	High--enemy unit response may differ from U.S. response
s/cm^2, static and dynamic pres- and damage.	Possibly feasible, with special instrumentation on selected equipment.	Small to medium--effects on aircraft could require special safety measurements.
ted pattern versus pattern actu- xperienced.	Feasible--CBRC does prediction and also plots actual events from monitoring reports.	Small to medium, in unlikely event that current prediction system is not sufficiently conservative.
data (x,y,z, and yield), static namic pressures.	Not feasible--burst data inexact and pressures would require instrumented battlefield.	Small
data, velocities and accelera-	Same as above.	Small
s for precursor effects.	Same as above	Small
s of interference in presence of louds, type and frequency of ent.	Feasible.	Small--effect is transitory and remedial actions are limited to those possible within existing nets.
ements by radars of cluttered reports of interference in pres- f fireball, type and frequency ipment.	Feasible.	Small to medium--chief benefit would be appreciation of radar blackout problem. Communications impact same as for dust cloud.
of casualties, survivors, and ent damage with associated dis- from GZ to outer limit of vis- damage.	Feasible; however, it would require significant manpower and there is high error potential.	Small--it is doubtful that a battlefield survey would develop a significantly different correlation than one computed based on EM-1.
data and doses received at a num- points.	Feasible, assuming either the thermal luminescent dosimeters or the current issue dosimeter.	Medium--would increase confidence in troop safety distances.

incapacitated. A cause for the uncertainty is that most current data are based on experiments with monkeys and is limited even there. Predictions of human response based on monkey response may have significant error. A chronological description of the impairment experienced by a number of men who have received a wide range of doses is required to fill this void.

Within a troop unit subjected to or near to a nuclear attack, there will be considerable differences in the doses received, because of variations in the postures of the men at the time of attack and their distances from GZ. Even men subjected to a dose causing immediate transient incapacitation* (and ultimately death) will have a period of partial recovery. At lesser doses, even though those doses may ultimately be fatal, there may not be even a temporary loss of capability. Hence, it appears feasible to interview men who have been exposed to radiation to determine the time history of their responses.

A major limitation to such an approach is the fact that the dosimeter now issued to troop units only reads to 600 rad (tissue) gamma. No neutron dose is measured. Also, the basis of issue is two per platoon and, depending on their posture, the doses received by the two men carrying the dosimeters might not be representative of the entire platoon. Because of the variances in individual exposures that might occur, it would be desirable to have at least every third or fourth man instrumented. To overcome these limitations it would be necessary to have dosimeters that would measure both gamma and neutron doses and cover the dose range of interest

*An early incapacitation followed by a temporary period of recovery.[3]

and to have a representative sample of men instrumented. Any dosimeter that would permit meeting these requirements would suffice. It is known that the U.S. Army has dosimeters under development; however details as to cost, size, and range of doses read are not known. As a matter of interest a small, cheap dosimeter used by ERDA is described below.

Based on information from a radiological safety expert in the Hazards Department at Lawrence Livermore Laboratory, it would be quite simple and cheap (about 20¢ per dosimeter) to equip every third or fourth man with a thermal luminescent dosimeter that could read to 10^4 rad (tissue). The part of the dosimeter that absorbs the radiation and provides the reading is a small cylinder of special material about 1 mm in diameter and 10 mm long. This cylinder could be enclosed in plastic and hung on a man's dog-tag chain. Since the cost of these tiny cylinders is insignificant, it would probably be desirable to enclose four cylinders in the plastic case, thus making a dosimeter set consisting of:

- Two dosimeters reading gamma dose--one up to 10^4 and one up to 10^3 rad (tissue).
- Two dosimeters reading neutron dose--same levels as above.

Supplemental equipment is needed to read a dosimeter, but it is packageable in a size about as big as a cased typewriter and could readily be used in the field. Because the actual reading must be taken at a site remote from the wearer of the dosimeter (and because the cost is small), it would be desirable to have replacement dosimeter sets available. This would permit detaching one set for reading and leaving a new unexposed one with the man.

Given gamma neutron dosimeters, it appears feasible to collect data on the variation of disability with time as a function of dose. Doctrine requires that irradiated personnel continue to fight until too sick to do so. Ultimately, however, the men who have received high doses and survived, at least temporarily, may be evacuated to an aid station or collected in a holding area, probably near an aid station. More often than not the tactical situation may preclude any attempt to interview survivors. However, interviewing a huge sample of cases is probably not necessary. With some additional training and with the provision of a questionnaire, the NBC personnel at company, battalion, and brigade could be used to interview survivors. The questionnaires would be similar to the one shown in Table 2. If data were being collected on radiation effects only, the interviewers would have to be careful to confine their examinations to men who had suffered only radiation exposure--avoiding men suffering from multiple effects.* The time history of the impairment experienced by a man who has suffered both burns and an initial radiation dose cannot be used as an input to a study of the impairment caused by radiation alone. A questionnaire would be filled out for each man interviewed and a dosimeter or a reading considered representative would be attached to a group of questionnaires. Depending on the time lapse since the burst, the interview team might need to remain at the aid station or holding area for some time to observe and note the onset of delayed responses. The NBC personnel

*The next part of this section covers collection of data on the effects of multiple injuries. If this were done the data collection would cover both radiation response and multiple injuries. The difficulty in finding radiation-only casualties suggests that examining multiple injuries would be preferable.

would return to their bases, the dosimeters would be read (probably at brigade), and the dose recorded on the appropriate questionnaire.

TABLE 2. ILLUSTRATIVE QUESTIONNAIRE FOR INTERVIEWING RADIATION VICTIMS

Were you ever unconscious?

If so, do you know how long?

Were you nauseated or did you vomit after the attack?

How long?

Were you dizzy or unstable?

Did you notice any other specific debilitations?

Were you burned or injured by the blast?

In the period immediately following the attack, did you notice any impairment of your ability to perform any of the following functions; if so, how long did the impairment last?

FUNCTION	NATURE OF PROBLEM	DURATION TIME
Fire a rifle or carbine		
Operate crew served weapon		
Use binoculars or other surveillance device		
Drive a vehicle or tank		
Read a map		
Operate a radio		

Did you observe impairments such as the above in others?

Who and nature?

The questionnaires could then be analyzed to determine what doses would cause:

- Immediate permanent incapacitation for demanding tasks.
- Immediate transient incapacitation (and time duration).
- No incapacitation.

If the sample of men interviewed was adequate, variances could also be determined.

The development of reliable data on the time variance of human capabilities as a function of dose could have great operational benefit. For example, if it was discovered that a particular level of incapacitation could be achieved with 2000 rad (tissue) in contrast to, say, 8000 rad (tissue), the yield used could be decreased by about a factor of four. In some cases this could be achieved by using a smaller yield option within a single weapon system; in other cases this could be achieved by using a different, smaller weapon system. Use of the smaller yield would reduce collateral damage and would permit an attack on targets closer to our own troops. This would be an example of criteria that were too stringent.

There is some uncertainty as to whether neutron doses and gamma doses are equal in causing rapid incapacitation. Thus, it is conceivable that the battlefield data collection and analysis could show that 8000 rad (tissue) are needed to achieve what we expected to do with 3000 rad (tissue). In this case, yield would have to be appropriately increased. In all cases, given proven data, we could operate with increased confidence.

In sum, the collection of battlefield data on the variation of human response versus time as a function of dose is both feasible and potentially of significant operational benefit. Accordingly plans should be devised to collect, evaluate, and disseminate such data.

B. Effects of Multiple Injuries on Personnel

To assess the potential importance of multiple injuries, a separate analysis was made of the significance and frequency of multiple injuries. This analysis is presented in Appendix C. In this analysis we found that multiple injuries increased the probability of death, and that there would be numerous multiple injuries.

This uncertainty is actually an extension of human response versus time as a function of radiation dose. In this extension we consider blast injuries and thermal effects (burns), as well as radiation dose. The data required are:

- A chronological description of the impairment experienced by a number of men who have received combinations of
  - A wide range of radiation doses.
  - A range of percentages of their bodies subjected to second and third degree burns.
  - A range of blast injuries (both as to type and cause).
- Unit activity and individual posture at the time of attack.

As is described in Appendix C, when a unit is subjected to nuclear attack, it is likely that men will be injured by blast, some will be burned, and some irradiated. By our doctrine we tend to target for a single effect--blast, thermal (rarely), or radiation. Considering only the one effect, we may seriously underestimate the total damage inflicted. Hence, knowledge of multiple injuries could give us valuable insight into the real status of an enemy unit we have attacked or one of our units attacked by the enemy.

In some ways it may be more feasible to collect the data needed to solve this uncertainty than it was for the previous uncertainty, which was only concerned with radiation dose. As we pointed out, a time history of the impairment suffered by a man who has received an initial radiation dose and whose body has suffered significant burns (or whose arm is broken) cannot be used as an input to human response versus time as a function of radiation dose. However, if the collecting team interviews an adequate number of men whose bodies have suffered 0%, 10%, 20%, and so on second and third degree burns (and similar varied levels of blast injury), the data generated may dispel both uncertainties. The data from the men with 0% burns and no blast injury will be used to answer the question of impairment versus time as a function of radiation dose, while the data from those burned and injured by blast will help to dispel uncertainties on combined effects. Because we would then be measuring percentage and degree of body burns and diagnosing blast injuries, the qualifications for the interview team would increase. The team members must be able to distinguish between degrees of burns and

estimate the percentage of the body that the burns cover, and they must be able to identify the nature and severity of blast injuries.

Analysis and evaluation of the data collected will be somewhat more complex than in "initial radiation only" cases. With the data collected here, one can estimate the percentage of a troop unit exposed to thermal radiation as a function of unit activity and the variance in that percentage. Also, the data concerning 0% burn and zero blast injury cases can be segregated to provide answers for questions in "radiation only" cases.

The operational benefit would be greater than that for human response versus time as a function of radiation dose. Given reliable data on multiple injury effects and on the expected percentage of a unit exposed to thermal effects, we could take into account thermal effects and multiple injury effects in our targeting and in post strike analyses. Thus, all of the operational benefits described under the previous uncertainty would be realized, and the accuracy of our planning should be greatly increased.

C. Loss of Effectiveness of U.S. Units as a Function of Casualties

Probably commencing with ORO-T-289,[4] a number of studies have sought to determine the percentage of casualties that a unit must suffer to cause it to lose its combat effectiveness. This original study examined cases of U.S. infantry battalions in WWII and arrived at percentages of casualties for two types of offensive action breaking points and one defensive action breaking point. Other similar studies examined Korean and Vietnam experience and

arrived at rather similar findings. Despite the caveats in the ORO study, its results (slightly modified) were assimilated into U.S. Army targeting practices. In fact, an aura of near magic attaches to a casualty figure of between 30% and 40%, and few users are familiar with the source studies on which these numbers are based.

There are several resultant weaknesses in our targeting. All of the case histories that served as inputs to these studies involved nonnuclear war, and the casualties were sustained over a period of from a number of hours to as long as two weeks. In contrast, casualties caused by a nuclear attack would in large part be virtually instantaneous. (The realization and recognition of all initial or residual radiation casualties would last for days.) Secondly, casualties in conventional conflict are often not directly associated with equipment damage (tanks being an exception) whereas most nuclear attacks that caused significant casualties would also damage equipment--thus increasing loss of effectiveness. Finally, despite the fact that the principal source study focused on infantry battalions, the 30% to 40% figure has been used on units ranging from platoon to theater forces; it seems very unlikely that the criteria that defeats a battalion will also apply to the defeat of a platoon or a theater force. Thus, there are major uncertainties regarding what level of nuclear-inflicted casualties will cause various types and sizes of units to lose their combat effectiveness.

The data required to resolve these uncertainties are:

- A listing of units (designation, type, and size) that are declared combat ineffective, the percentage

of casualties that each suffered, and a description of equipment damage.

- A brief description of the near-term prior experience of these units (prior casualties, exhaustion, and the like).
- For each unit, the time at which it was declared ineffective and the time (if ever) that it was again considered combat effective.

Most of the foregoing data could be collected from regular reports that would be received at brigade and division command posts. It would probably be desirable in selected cases to visit the stricken units to verify the casualty figures and equipment damage. In the confusion of such a situation, the reporting might well be inaccurate. However, if the focus of the effort were on units declared ineffective even though they had suffered less than 50% casualties, it should be possible to collect the essential data.

The Technical Project Monitor suggested that a unit's breaking point might be from equipment damage as well as casualties. However, two factors argue that this investigation should be in terms of percentage of casualties. First, there will often be a close correlation between percentage of casualties and damage to equipment; hence, making the assessment in terms of casualties does not ignore equipment damage. Second, the operational reports concerning the nuclear attack and the damage inflicted will tend to be more accurate on casualties than on equipment--a commander's first concern is his men. Therefore, the basic concept of indexing the breaking point to casualties is retained.

The operational benefit could be significant. Our targeting criteria might be far too stringent. In that case, assuming that enemy unit response was similar to ours, smaller yields could be used, and collateral damage and risk to our forces would be reduced. Conversely, if we found that current criteria were inadequately low, we could use larger yields. In either case, we would gain increased confidence in our targeting. The findings would also provide some quasi-quantifiable data on the psychological impact of nuclear weapons.

D. Loss of Effectiveness of Enemy Units as a Function of Casualties

Since an enemy unit's response to sudden, heavy casualties might not be similar to that of a U.S. unit,* it would be desirable to have separate data on the percentage of casualties that would cause enemy units to become combat ineffective, and for how long. The type of data required would be essentially the same as that required to determine the breaking point for U.S. units.

Collecting meaningful data on loss of effectiveness on enemy units would be difficult. Even in the uncertain event that U.S. forces overran major enemy headquarters, there would be no

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*At any given time in history, the combat performance and stamina of troop units varies considerably with nationality. For example, during WWII Wavell, with 36,000 Commonwealth forces, virtually destroyed an Italian force of ≥250,000. Yet, the subsequent injection of two German divisions into that theater nearly reversed the course of that war.

assurance that the pertinent records would be recovered and properly interpreted. Some relevant information could probably be obtained in POW interrogations. Also, when U.S. units mounted counterattacks supported by nuclear weapons, enemy casualties could be estimated with some accuracy and correlated with the effectiveness of enemy opposition to the attack. Even though the ability to acquire sufficient data from which to form accurate conclusions is uncertain, the cost of attempting to acquire it is small. Some key questions could be asked by POW interrogation teams and certain relevant matters would be in after-action reports.

If the data were obtained, the operational benefit would be high because we could then target the enemy with more confidence. Hence, plans should be made to collect pertinent data.

E. Combined Thermal and Blast Effects

Equipment that has been heated by thermal effects may become more vulnerable to blast. The data required for a variety of equipments are:

- Calories/cm^2
- Overpressure and dynamic pressure.

Strips of paint on equipment or attached pieces of plastic that change color with heat could permit the amount of thermal exposure to be determined. Crush or deformation type gauges could be attached to permit the reading of the total or integrated pressure experienced. Damage would, of course, be observable.

Again installing instruments to measure dynamic pressures would be expensive and their durability would be questionable. However, in many cases the total pressure would be the phenomenon of interest. Hence, collection of meaningful data on the battlefield is deemed feasible.

Given that data collection is feasible, what is its operational value? Most of the ground force equipment that is targeted for its own sake--tanks, vehicles, and artillery--is not the equipment that might be seriously affected by this double exposure. The equipment most likely to be affected is semisoft equipment--radios, microwave repeaters, radars--usually treated as bonus targets. Hence, improved knowledge of combined effects on this equipment would not be important operationally.

Air weapon systems present different problems. The high-performance aircraft itself could be vulnerable to the combined effects. However, the data collected in the case of aircraft would tend to be negative. If a plane exposed to a nuclear environment returned to base and the instrumentation showed the thermal and total blast exposure, we would know that these combined levels were not lethal. Analyses of data from surviving aircraft, combined with data on the environments encountered by aircraft that were lost, might indicate which combinations of blast and thermal levels were lethal. If this proved true, we might need to modify our air tactics to provide safety from our own bursts. In summary, full knowledge of the combined effects of thermal and blast could change our estimates of safety criteria for aircraft, thus

leading to some modification in tactics. Hence, the operational benefit of these studies might be small or medium.

F. Adequacy of Fallout Prediction

Field Manual 3-22[5] describes what is believed to be a very conservative fallout prediction system. If the system operates as intended, the areas that it predicts as hazardous will more than encompass the areas that are actually hazardous. (There probably will be areas within these predicted hazardous areas that are safe.) However, gross underestimation of the yield of an enemy weapon could result in underestimation of the size of hazardous area. Therefore the actual performance of the system would need to be verified by comparing the predicted pattern with the actual pattern.

The division CBRC does the fallout prediction. It also plots actual fallout patterns based on monitoring and survey reports from division units. Thus, the collection of the required data is planned for in current doctrine.

The principal benefit of verifying the adequacy of the system would be increased confidence. In the unlikely event that significant fallout was discovered with any frequency outside of the predicted hazardous area, additional buffer zones could be added immediately. The overall benefit is judged to be medium.

G. Precursor Effects

Precursor uncertainties are related to the static and dynamic pressures associated with a low air burst that generates a precursor wave. The data that would be required to dispel the uncertainties include:

- Knowledge that a precursor wave occurred.
- Burst location (x, y, and z) and yield.
- Local terrain and meteorological data.
- Static and dynamic pressure readings at a number of points (adequate sample) distributed over the area affected.

To obtain such data would require a major, sophisticated instrumentation effort--fast-response dynamic pressure gauges capable of measuring pressure versus time, an accurate burst detection and location system, static pressure gauges, surveyed instrument locations, and the like.

In DNA EM-1,[3] the reliability of predicted distances for peak overpressure from nonprecursor bursts is typically ±15% while reliabilities for peak dynamic pressures can be from -50% to +100%, depending on the pressure and surface involved. These predictions are based on atmospheric tests where the GZ and HOB were known, the yield was usually known within ±10%, and sophisticated instrumentation was used to record pressure data.

In contrast, errors in data collected on the battlefield* can be expected to be from 100 to 400 m in GZ location, and estimated

*See Appendix A.

yield may be seriously in error. HOB data will show only surface or air burst. Further, as troops are now equipped, there are no instruments for reading any type of pressure. Hence, without adding extensive supplementary equipment, there is no capability to acquire data that would improve our knowledge of precursor effects. Further, instrumenting the battlefield is not an attractive concept.

Conceivably, a simple crush-type gauge could be built and attached to selected equipment items. These might permit total pressure to be estimated--but not dynamic pressure alone (which is important in precursor effects). Any widespread use of more sophisticated instrumentation would be expensive. Also, in general, the more sophisticated the instrument, the greater would be its vulnerability to damage in ordinary military usage.

In summary, expected inaccuracies in burst data and the infeasibility of instrumenting the battlefield argue that battlefield data that would improve our understanding of precursor effects could not be collected.

In any event, the operational benefit of perfect knowledge of precursor associated effects would not be dramatic. Operating with systems with fixed yield options, it is doubtful that perfect knowledge would cause a choice of a different yield than the one chosen on the basis of current knowledge. Hence, uncertainties regarding precursor associated effects will not be examined further.

H. Blast and Ground Shock Effects from a Surface and Shallow Underground Burst

The data required to study the effects of a shallow underground burst would be:

- Knowledge that the burst was shallow or underground.
- Location of GZ and yield.
- Local terrain and meteorological data.
- Static and dynamic pressures (versus time) and velocities and accelerations at a number (adequate sample) of points distributed over the affected area.

Most of the discussion under Precursor Effects is also pertinent here. Because ground shock is included, the required instrumentation would be even more complex (accelerometers and velocity gauges). Accordingly, the conclusion is the same: collection of useful data on the battlefield would not be practicable.

I. Effect of Dust Clouds on Communications and Radar

Although it is thought that dust clouds will cause some interference with radio and radar operations, the extent and duration of this interference is not well understood. The data needed to increase understanding can be obtained from:

- Reports of link outages, interferences, or clutters in the presence of nuclear dust clouds, and their durations.
- Type and operating frequency of affected equipment.

Given the presence and characteristics of a dust cloud, persons using radios or radars would report the time duration of

outages or interferences on links. Some radars could measure the size and duration of the clutter patch. If these data were logged and assembled at the CBRC, they could later be analyzed to improve insight into the dust problem. Thus, data collection is deemed feasible.

Since dust moves with the wind, any problems created will be transitory. Where radio nets are temporarily blocked, SOPs should specify alternative routings (including relaying of messages). If a radar operator finds a significant amount of his assigned search sector cluttered, he could report that to his controlling echelon, which in turn should modify the search sectors of other radars so as to provide adequate coverage.

The major point is that the current systems are already prepared to take remedial action when troubles (such as equipment outages) occur, and they will do this if dust creates troubles. Further, because of the temporary nature of the problem and because of possible remedial actions being limited to those that can be undertaken with the equipment already deployed on the battlefield, there is little more that could be done. Therefore, increased knowledge of problems generated by dust will be of small immediate operational benefit.

J. Fireball Volume Causing Interference to Radar and Communications

Nuclear fireballs may block both radar and radio. Furthermore, ionization and particulate matter outside of the visible fireball may cause the volume that interferes with EM propagation

to be considerably larger than the visible fireball. The information needed to increase our knowledge base is:

- Measurements of apparent fireball size by radars, preferably by radars of each frequency present on the battlefield.
- Reports of radio link outages or interference in the presence of fireballs, and the duration of those effects.
- Type and operating frequency of affected equipment.

The radar measurements of the fireball should be obtainable. They could be made at the same time that radar observations are being made to determine ground zero. Radio link outages should also be readily obtainable. However, radio reports will only provide a measure of the overall severity of the problem; they will not permit precise estimates of the size of the interference volume--whose size will vary with equipment frequency.

The operational benefit is much the same as that for dust cloud interference. Because of the rise of the fireball, the effect will again be transitory, and again system elements will take SOP remedial actions. Better knowledge of the size of the interfering volume would permit improved planning for the impact of our own bursts on radar operations. The benefit is judged to be small to medium.

K. Correlation Among Visible Damage to Structures, Tree Blowdown, Personnel Casualties, and Equipment Damage

If there were an established correlation between damage visible from the air and damage not readily visible, the accuracy of

poststrike analysis from an aircraft (visual or photo) would be enhanced. The data required to establish a correlation would be:

- Estimated counts of casualties and survivors with associated distances from GZ to the outer limits of equipment damage, damage to structures, and tree blowdown.

- Estimated counts of damage to equipment associated with distances from GZ to the outer limits of damage to structures and tree blowdown.

DNA EM-1 has effects data on tree blowdown, blast damage to structures and vehicles, and damage criteria for personnel from various effects. Hence, a correlation could be developed between visible and invisible blast damage and casualties based on EM-1, and to use this in poststrike analyses. One shortcoming of such a calculated correlation, as opposed to one developed by actual survey on the battlefield, is that it would necessarily ignore casualties arising from multiple effects (e.g., blast and thermal). Also, it would not reflect the casualties caused by the environment, such as men hit by flying debris and equipment.

A possible method for collecting battlefield data would be to send a ground survey party down a swath from the outer limit of visible damage to the zone of total destruction (people and equipment). However, there are several difficulties. Some casualties, at least the walking wounded, will have been evacuated. Unless dosimeter readings are available, the lower dose radiation casualties may not be identified as casualties. Finally, with small weapons, radiation effects will be dominant and the visible results of the blast will be confined to a small area. The drop-off in

blast as yield is reduced suggests that there would be problems in scaling the correlation between visible blast damage and casualties. Thus, data collection seems feasible but there are significant possibilities of error.

As previously indicated, the chief operational benefit of developing such a correlation would be to obtain more accurate poststrike analyses based on visual observation or photos from an aircraft. However, simply eyeballing the area of devastation, or examining photos of it, would tend to be imprecise. Such a method would lack refinement--for example, an air observer might not be exact about the types of trees blown down. Hence, unless the correlations established by battlefield surveys were dramatically better than the correlations derived from EM-1, the poststrike analysis based on the former correlation would probably be only moderately better than those based on an EM-1 correlation. The complexities of multiple effects preclude absolute judgment as to the degree of improvement. If the findings of the poststrike analyses do not differ greatly, operational decisions based on the analyses will not be much different. Therefore, the operational benefit of having a correlation based on a battlefield survey is judged to be small to moderate. Since the resources available for collection of effects data on a tactical nuclear battlefield will be small, we have developed no plans for surveys to establish the correlations.

In the foregoing analysis, we considered correlations among visible damage and casualties that could be derived from data now available in EM-1. No such correlation data are presented in EM-1; yet, having such a correlation would be quite beneficial in

making poststrike analyses. Accordingly, we recommend that such correlations be developed and incorporated into EM-1. The correlations should show the anticipated effects on personnel and equipment as a function of visible damage to structures and trees. Different correlations may need to be developed for different weapon designs. A preliminary analysis developing such correlations is presented in Appendix B.

L. Radiation from a Vent Stem

The radioactive debris erupting from a shallow or deep underground burst generates an unknown amount of initial radiation. The data required to understand this phenomenon are:

- Burst data--ground zero, depth of burst, and yield.
- Initial dose received at a number of points at varying distances from the stem.

The crater would be used to locate ground zero. A suppressed thermal flash would indicate that it was a subsurface burst. An approximation of yield and depth of burst could be based on crater size and depth.

Assuming that troops were wearing thermal luminescent dosimeters, the simplest method of determining the radiated dose would be to collect dosimeters from men who were in an exposed posture at the time of detonation. The coordinates of the man at time of burst (as well as his name and unit) would be attached to the dosimeter. The reading of the dosimeters could be done at the echelon where the reading device was located. Radiated doses

could also probably be obtained by readings from fountain-pen-sized dosimeters, assuming that the doses are less than 600 rad (tissue) gamma.

The chief operational benefits from having better data on the initial radiation emanating from the vent stem of a subsurface burst would be (1) better data on which to base troop safety distances, and (2) possibly improved ability to estimate enemy casualties. There might be a bonus benefit of more accurate estimation of collateral damage.

It would require a significant number of man-hours to collect the dosimeters, record their sources, and read them. Also, analyzing a fresh crater (probably by photo interpretation) to get burst data is not simple. In view of these costs, the decision to collect such data on the battlefield should be based on the expected frequency of our use of subsurface bursts. Based on discussions with SRI and DNA staff, it is recommended that no plans for collecting this data be developed.

IV PLANS FOR BATTLEFIELD COLLECTION, ANALYSIS, AND DISSEMINATION

A. Collection

In the preceding section, we analyzed the feasibility of battlefield collection of data on the identified uncertainties and examined the possible operational benefit of dispelling the uncertainty. In this part of this section, we will develop specific plans for data collection on those uncertainties that passed the tests of collection feasibility and operational benefit. The findings are summarized on Table 3.

1. Human Response Versus Time as a Function of Radiation Dose

After a troop unit has suffered a nuclear attack there probably will be men who have sustained high-radiation doses who temporarily survive and can be interviewed. If they are equipped with the thermal luminescent dosimeters, their radiation exposure can be measured and correlated with their descriptions of their response.

In many cases the tactical situation will preclude such interviews. However, a review of thousands of cases is probably not necessary. If 600 to 1000 men who had received a range of doses could be interviewed, the uncertainties regarding radiation response could be considerably reduced. In past wars the tactical

TABLE 3. COLLECTION OF DATA ON EFFECTS UNCERTAINTIES

UNCERTAINTY	PROPOSED METHOD OF COLLECTION
Human response versus time as a function of radiation dose.	Equip selected men with gamma neutron dosimeters. When the tactical situation permits, dispatch trained interview teams from brigade or division to collect dosimeters and interview survivors. Read dosimeters and analyze data at the appropriate echelon and analyze data.
Effects of multiple injuries to personnel (combination of blast, thermal, and radiation).	Same as above plus interview team diagnoses and records extent of burns and blast injuries for each man interviewed.
Loss of effectiveness of U.S. units as a function of percentage of casualties.	At Bde and Div CPs, record percentage of casualties and prior recent history for U.S. units declared combat ineffective. Make some on-scene surveys to verify percentage of casualties. Also record time to return unit to combat effective.
Adequacy of current fallout prediction system.	CBRC at Div TOC takes fallout predictions and receives and plots actual monitoring and survey reports. Compare actual with predicted doses and note discrepancies.
Combined thermal and blast effects on aircraft.	Instrument aircraft with plastic or paint strip that will change color with thermal exposure, and a deformation type pressure gauge. Read instrumentation on planes that have survived nuclear environments.
Loss of effectiveness of enemy units as a function of percentage of casualties.	Special questions for POW interrogators. Special after-action report items for attack forces that have exploited U.S. nuclear strikes.

battlefield has tended to move in spasms and this may also be true of a tactical nuclear battlefield. Thus, in the ebb and flow of the battle there may well be opportunities for interviewing radiation victims.

If each U.S. echelon (division to company) trained selected NBC personnel, an interviewing team could be formed when needed. The team could be sent to the holding area where the irradiated survivors were located to collect the dosimeters and fill out questionnaires (similar to Table 2) on the survivors' description of their response history. The dosimeters could then be read and the dose readings could be correlated with the response descriptions and forwarded to the Corps CBRE for analysis.

Summarizing, the actions required to make collection feasible would be to:

- Procure and issue the gamma neutron dosimeters to be carried or hung from dog-tag chains.
- Equip appropriate echelons with the devices needed for reading the dosimeters (if required).
- Designate and train selected NBC personnel at each echelon to act as interviewers.

2. Effects of Multiple Injuries to Personnel

Basically the same plan of collection as that described above (for radiation) would be used for collecting data about injuries. Variations needed would be the following:

- The interview team will have to be trained to diagnose and describe burn and blast injuries.
- Because of the increased scope, the survey teams should be increased to ten men each.
- The questionnaire would need to be expanded.

3. Loss of Effectiveness of U.S. Units as a Function of Casualties

In general, a unit will be declared combat ineffective by its superior echelon (possibly on recommendation of the unit commander). Whenever such a declaration is made, there will be messages to the brigade and division TOCs stating the designation of the unit, the nature of the catastrophe, the damage sustained by personnel (and possibly to equipment), and the expected time of return to some level of effectiveness. Hence, what is required to collect data on this uncertainty is that brigade and division TOCs forward copies of these messages to corps CBRE, adding a brief description of the unit's recent experience--prior casualties, fatigue, and so on. In cases where the data seem abnormal, the corps CBRE--after a suitable interval and during a lull in the action--should query the originating TOC as to whether there have been revisions in the estimated damage.

4. Adequacy of Current Fallout Prediction System

As was previously indicated, a concern is whether or not a predicted pattern does in fact cover all of the danger areas. Current doctrine already provides for the division CBRC making

fallout predictions and plotting actual fallout based on monitoring and surveys made by division units. Thus the necessary data can be obtained by simply requiring division CBRCs to report to corps CBRE any instances where local areas of intense radioactivity occur outside of the predicted danger zones.

5. Combined Thermal and Blast Effects on Aircraft

Does thermal exposure weaken aircraft components to the point where their resistance to blast is significantly reduced? To answer this question, the plan developed in this report is to instrument aircraft with a strip (paint or plastic) that will change color with thermal exposure and a deformation type gauge that will measure total pressure. When a plane returns to base after being exposed to a nuclear environment, this instrumentation would be examined. If there were positive readings they would be taken and reported together with any damage noted--the U.S. Air Force probably reporting to the DASC (and possibly numbered Air Force) and the Army to corps CBRE. The instrumentation would then be replaced. These readings would show what combinations of effects will not kill the aircraft.

6. Loss of Effectiveness of Enemy Units as a Function of Casualties

To explore the uncertainty about the breaking point of enemy units as a function of casualties, the collection concept is to use POW interrogations and after-action reports from U.S.

units that have attacked enemy forces with nuclear fire support. The actions required to provide for such a collection are to:

- Develop special questions for POW interrogators that will probe this point--e.g., How many casualties did your unit take? Was it then out of action? How long?
- Develop a list of items to be observed and reported by units exploiting nuclear fires--e.g., estimated nuclear casualties in enemy units overrun, estimated equipment damage, and effectiveness of enemy resistance.

B. Analysis and Dissemination

From the reporting procedures already described, it will be apparent that it is planned to have most of the data analyzed at corps CBREs. This echelon was selected for several reasons. It is far enough to the rear to provide some safety, yet far enough forward to have fairly ready access to the fighting units. Being well forward also simplifies communications. Putting the responsibility at corps level, rather than at field army level, also provides some redundancy (i.e., there are two U.S. Corps in NATO). Finally, the staff at the corps CBRE should be somewhat larger than at division and should thus have a better capability for making the analysis.

One exception is the analysis of data concerning the combined effects of thermal radiation and blast on aircraft. That portion of these data that relates to USAF aircraft will originate at USAF bases. Because of communications, familiarity with the problem,

and proprietary interest, these data should be analyzed at the DASC. The Army portion of these combined effects data should be analyzed at the corps CBRE; however, a knowledgeable army aviator from the corps aviation section should either assist or supervise the analysis.

When a corps CBRE makes a finding concerning an uncertainty, it should be cross checked with an adjacent corps CBRE and with the Army CBRE to make certain that there are not conflicting findings. If there are no conflicts and the Army CBRE approves, the findings should be immediately disseminated. Findings on those uncertainties that pertain primarily to ground targeting should go to all staff elements involved in nuclear planning or targeting, namely all TOCs, DASCs, and FSCCs. Findings on uncertainties relating to army aircraft vulnerabilities should go to all army aviation units and to those TOCs and FSCCs that may request or control army aviation elements.

Similarly, when a DASC has findings on USAF aircraft vulnerability, it should cross check with another DASC and the TACC. With no conflict, and with TACC approval, the finding should be reported to all air bases and all TACPs. (TACC will probably report the finding to all number air forces.)

To the extent possible, the findings should be anticipated and plans should be made to make appropriate changes in doctrine. These could be in the form of change pages to service weapon employment manuals (e.g., Army FM 101-31). However, in a battle area it would probably be more expeditious to have prepared

fill-in-the-blank type messages which could be sent at once to all interested headquarters. Examples are:

> "Battlefield data indicates that ________ rad (tissue) are required to cause immediate transitory incapacitation."

> "Experience thus far indicates that the infliction of ________% nuclear casualties on a ________ size infantry unit will cause loss of combat effectiveness in the attack."

V TACTICAL NUCLEAR WARS WITHOUT U.S. INVOLVEMENT

It was suggested by the client that the first tactical nuclear war might be one in which U.S. forces are not involved. There are already enough lesser nuclear powers to give credence to this possibility, and numerous proliferation studies suggest that there will be more.

During the conflict, some useful observations might be made by surveillance satellites--the progress of the war, where battles were, and numbers of weapons. After the conclusion of the war, a number of situations might prevail:

- The interchange occurred between two powers, in which at least one is friendly to the United States, such as an Israeli-Arab war.
- The interchange occurred between powers, none of whom are friendly, but U.S. personnel might gain postwar access, for example, in a "peacekeeping" or "mercy force" role.
- It is an interchange in which neither power is friendly, and U.S. personnel are not allowed on the scene.

In the first situation, it might be possible to preposition equipment and to insert some instrumentation before the war. It might also be possible to enter the battlefield within hours or days after the nuclear interchange. In the second situation, it would not be possible to preposition equipment before an interchange,

but entry might be possible within a useful time after the battle. In the third situation, data could be obtained only through use of remote sensing techniques, such as drones, cameras, satellites, or radio monitoring.

For the purposes of this report, the question is "What could observers who were permitted on scene learn that would benefit our knowledge of nuclear effects uncertainties?" Reexamining Section IV, in which we developed plans for data collection on uncertainties in a situation where the United States was involved, it is evident that many of the collection plans entailed some instrumentation--dosimeters and deformation gauges. Manifestly these could not be applied ex post facto. However, if the United States was providing military assistance to one of the participants, it could furnish aircraft equipped with deformation gauges and thermal exposure indicators. Thermal luminescent dosimeters could conceivably be imbedded in military web equipment or buttons. The political implications of such acts would have to be carefully assessed.

If allowed to interview medical officers, our observers might get interesting data on the frequency of combined effects injuries. If sufficient time had elapsed before our observers' arrival, and if it was within the competence of the medical corps of the country, medical officers might have diagnosed from symptoms what approximate radiation doses various patients* had received. Thus it might be

*The patients might be from the medical officer's own forces, or POWs.

possible to get quite useful data on the frequency of various combined effects. Also, medical officers might be able to furnish good descriptions of the total casualty situation within units that had been hit--the total picture might be more interesting and important than its parts.

If allowed, discussions with operational commanders and staff might furnish valuable insight on unit losses of effectiveness with casualties. After a unit was hit, suffering X percent casualties, did the survivors panic or fight on? How effective was their resistance?

It would also be interesting to visit the battlefields. It is doubtful that they would have completely policed the battle area, and much of the damaged equipment would still be in place. If a collaborating former participant would provide data on what yields were used where, and at what height of burst, it might be possible to reconstruct the battle scene. An air photo would show the location of the derelict equipment relative to GZ, and a ground survey could record the damage. Such a survey could produce excellent data on the vulnerability of the equipment present. These data would be particularly interesting if the damaged equipment had been furnished by a potential U.S. enemy or if it was equipment of U.S. manufacture that had not previously been tested in a nuclear environment.

Even if the participants were unwilling to furnish weapon and burst data, a careful analysis of the residual-induced radiation would provide an estimate of the yield and the location of GZ.

Thermal, and possibly neutron, shadows might permit estimating height of burst. All of this, of course, assumes free access to the battle area.

To a great extent our ability to obtain useful information from a non-U.S. tactical nuclear war would depend on the effectiveness of our prior planning. It would be valuable to make a study examining:

- The likely areas where tactical nuclear wars without U.S. involvement might occur and, for each area, the probable rules that would govern U.S. observer access to data.
- The key commanders and medical officers who should be interrogated, if possible, and their political leanings to include their attitude toward the United States.
- The questions that should be asked of key participants.
- The number and types of observers and equipment that it would be desirable to send to each of the potential areas, based on the anticipated access to data rules.
- The training required for candidate observers.
- The instruments and other equipment that should be stockpiled and where.

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Appendix A

BURST DATA BASED ON NBC REPORTS

The Army nuclear burst reporting system* is designed to provide information for determining (1) the time of detonation, (2) the location of GZ, (3) an estimate of yield, and (4) whether the burst is likely to produce fallout. These data are useful inputs to the assessment of the impact of nuclear weapons on current operations. Both enemy and friendly nuclear weapons are considered.

The collection of nuclear burst information is made principally by artillery units based on observations and measurements of the nuclear cloud at certain times after detonation. In this section a brief analysis of the methods employed and the precision with which the information can be reported will be made.

1. Location

Burst location can be determined by two ways: map inspection and intersection.† If a crater exists and can be seen, map or

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*FM 3-12[1] specifies that a reporting unit must use the NBC-1 report format; this conforms to the nuclear part of STANAG 2103.

†Intersection is essentially a form of topographic survey that constructs a location by using azimuthal observations from several known locations.

aerial photo inspection will permit the fixing of the location quite accurately (i.e., ±50 meters). In the case that may prove to be more common, when the burst is an air burst with no crater, the GZ will be located by intersection on the cloud stem. In this case the stem of the nuclear cloud is observed, and azimuths are read from several locations. The intersection of the rays from the observer locations provides a location of GZ. The precision with which it can be located depends on the precision with which the observation points are located, the accuracy with which the angles are measured, and the ability of different observers to define a common aiming point on the stem. There is also an inherent error due to the fact that observations cannot be made until after the blast wave passes the observer. This may result in delays on the order of 10 to 30 seconds, during which time the stem moves with the wind. Intersections based on readings from surveyed baselines of known direction could be quite accurate--on the order of ±10 meters plus errors due to wind movement of the stem and errors due to different aiming points on the stem. Intersections based on observations from unsurveyed ground locations and using a magnetic azimuth reference will be less precise. In summary, it would be unwise to expect overall location accuracies better than 100 to 400 meters.

A requirement when constructing a location by intersection is that all observers must be taking measurements on the same cloud stem; otherwise gross errors can result. In a situation in which multiple detcnations are encountered, sighting at the wrong cloud will result in a number of false locations.

Although errors in location of a nuclear detonation can initially be large, in time the location could conceivably be fixed with adequate precision based on location of the crater or other centroidal indicators in the distribution of damage and induced radiation. However, considering the time urgency involved, the limited human resources available for such investigations, and the inherent confusion of war, the practicability of doing this on the battlefield is very doubtful.

2. Air or Surface Burst

The operational technique for determining if the detonation occurred in the air (creating a fallout free condition) or not is based on visual inspection of the cloud stem. Observation of a thick, dense stem connected to the mushroom cloud is indicative of a surface burst. If, however, the cloud is not connected to the stem, an air burst is indicated. Observation of a throwout, an inspection of the crater at a later time, or downwind residual radiation can indicate that a surface or near surface (above or below) burst occurred. In general, the actual height of burst for air bursts may not be quantified by visual observation. Moreover, night or reduced visibility may preclude a determination of air or surface burst.

3. Yield Estimate

Estimates of yield are based on known, empirically determined cloud stabilizations of heights and diameter. Visible measurements are made of cloud diameter at five minutes and cloud height

at approximately ten minutes after detonation. This latter time should ensure that the cloud has ascended to its stabilization height.

Except for aerial observation of cloud height, all other height and diameter measurements are based on a measurement of a subtended angle and an estimated observer distance. From these two measurements, cloud height and width are calculated.

Atmospheric testing provides data for predicting yields based on cloud properties. Emperical relationships relating cloud top, bottom, and diameter to yield have been developed. One such set of relationships resulted from a comprehensive analysis of U.S. atmospheric tests.[6] These provided the basis for the nomographs used by the Army for yield prediction in the field. A summary of these data is presented in Figure A-1 in which cloud top, bottom, and diameter relationships are indicated as a function of yield. Estimates of error in the predictions are shown by the shaded area in the figure.

The general relationships in Figure A-1 are those of power curves with the cloud property proportional to a fractional power of yield within ranges of yields. In the data, yield was known to ±10% or less; scatter in the cloud data accounts for the uncertainties indicated by the error bands.

It is noteworthy that the functional relationships change for the cloud stabilization altitude data between the yields of 2 and 20 KT. This situation is only in part explained by the altitude of the tropopause. For high yields, testing was conducted

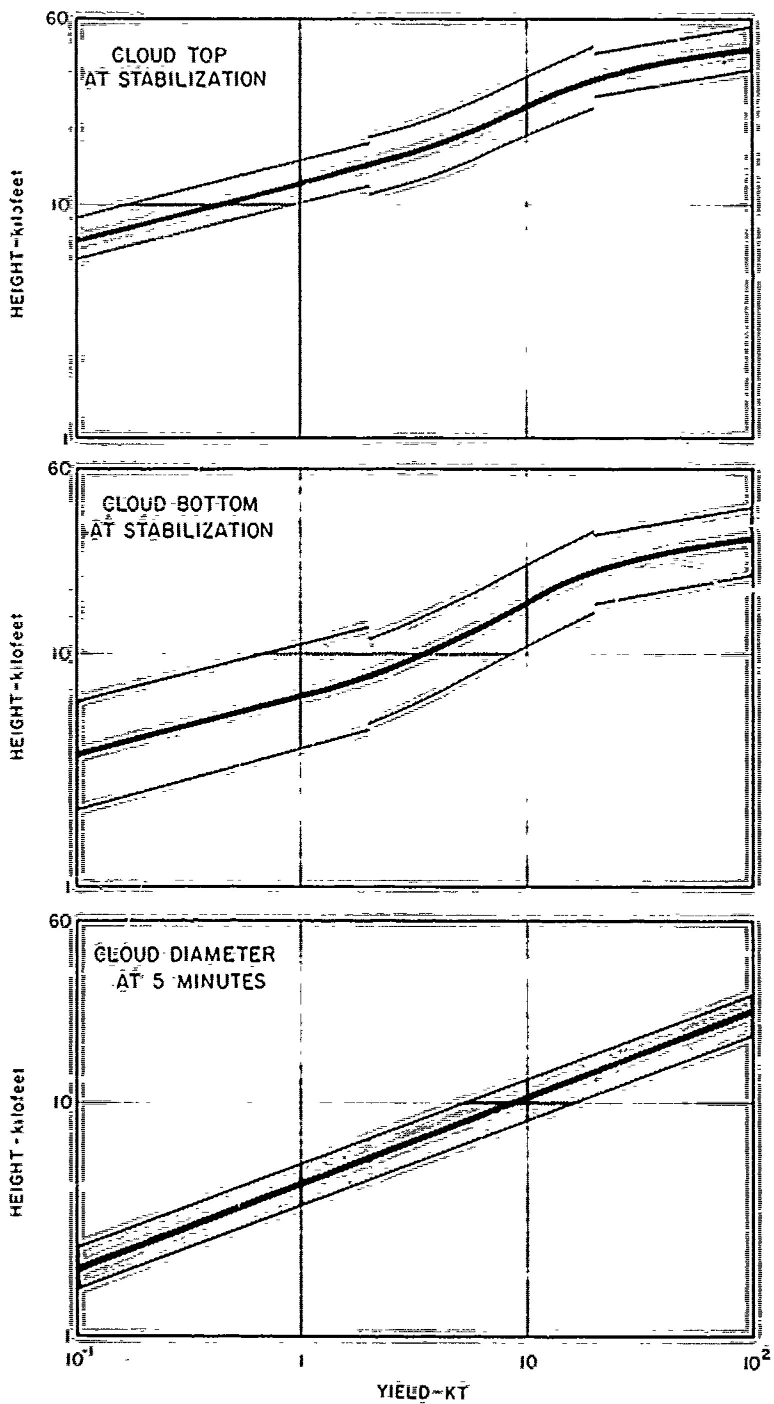


FIGURE A-1. CLOUD PARAMETERS

in equitorial areas where the tropopause is customarily at an altitude of 54,000 to 60,000 feet. A high yield model for yields greater than 2 KT is postulated for predicting stabilization altitudes. Other testing was done at the Nevada test site where the tropopause is at 33,000 to 40,000 feet. A model for yields less than 20 KT is suggested.

The ambiguous conditions presented in the yield range of 2 to 20 KT are accommodated in practice in the field manual by use of a nomograph solution. The functional transition between the two yield relationships is shown in Figure A-1. This relationship is embedded in the nomograph in FM 3-12[1] and appears to minimize the prediction error.

There are curves that permit yield predictions based on cloud diameter at varying times after detonation. Cloud diameter at five minutes after detonation is built into the nomograph solution found in FM 3-12.[1]

In comparing the nomograph solution for estimating weapon yield with the body of experimental data, a large variance exists. Yield predictions based on cloud stabilization heights for all clouds stabilizing between 14,200 and 35,000 ft (corresponding to 2 KT and 20 KT respectively) showed a standard deviation of +113% and -57%. For example, according to FM 3-12 a measured cloud stabilization height of 20,000 ft corresponds to 10 KT; however, a weapon yield of 4.3 to 21.3 KT could have produced this same result.*

*This is a one-sigma estimate--a 68% confidence band, if distribution were normal.

Variability to a lesser degree results from the prediction of yield based on cloud diameter. When comparing the prediction model in FM 3-12 with measurements of the five-minute cloud diameter from atmospheric testing, a standard deviation of +58% and -37% was found to be present for yields greater than 2 KT.*
From a cloud width corresponding to that of a 10 KT weapon there is a one-sigma uncertainty range of 6.3 to 15.8 KT.

In an operational context, both measurement errors and prediction errors must be considered. A measurement error, for example, of 10% in cloud stabilization altitude or diameter appears to be consistent with uncertainties in angular measurements, distance estimates, and local wind conditions. This 10% error in altitude or in diameter translates to a yield error of 44% or 26% respectively. Considering the previously established precision of the prediction model, standard deviations on yields developed from measurements of cloud properties can be +120% and -70% based on cloud stabilization altitude, and +60% and -45% based on cloud diameter. In terms of the 10 KT example previously illustrated, the one-sigma band for prediction is 3 to 22 KT based on stabilization, and 5.5 to 16 KT based on cloud diameter.

*Although the nomograph indicates that yields may be calculated to 1 KT, the error associated with predictions at 1 KT was found to be excessive.

Appendix B

CORRELATION BETWEEN VISIBLE BLAST DAMAGE, CASUALTIES, AND EQUIPMENT DAMAGE

As was discussed in the main body of the report, it would be useful to establish correlations between visible blast damage, personnel casualties, and equipment damage for use in tactical damage assessment or post-strike analyses. The concept is that an observer might quickly identify the limits of various types of blast damage and that, from this intelligence, a fairly accurate estimate could be made as to what happened to people and equipment in certain areas. The concept is pertinent both to a tactical damage assessment of the effects of a friendly strike on enemy forces and to an evaluation of damage inflicted by an enemy strike on our own forces.

A good way to implement the concept would be to have the observer airborne. Aloft he could quickly discern the limits of various types of damage and denote these on a map or photo--or he could actually photograph the area of damage. For assessments over enemy territory a drone with a TV or photographic camera could be used. The damage most readily detected by an air observer is estimated to be tree blowdown and damage to structures. Severe damage could probably be more readily distinguished than light or moderate damage. In some cases he might detect damage to vehicles, but it would be unwise to depend on this. (The

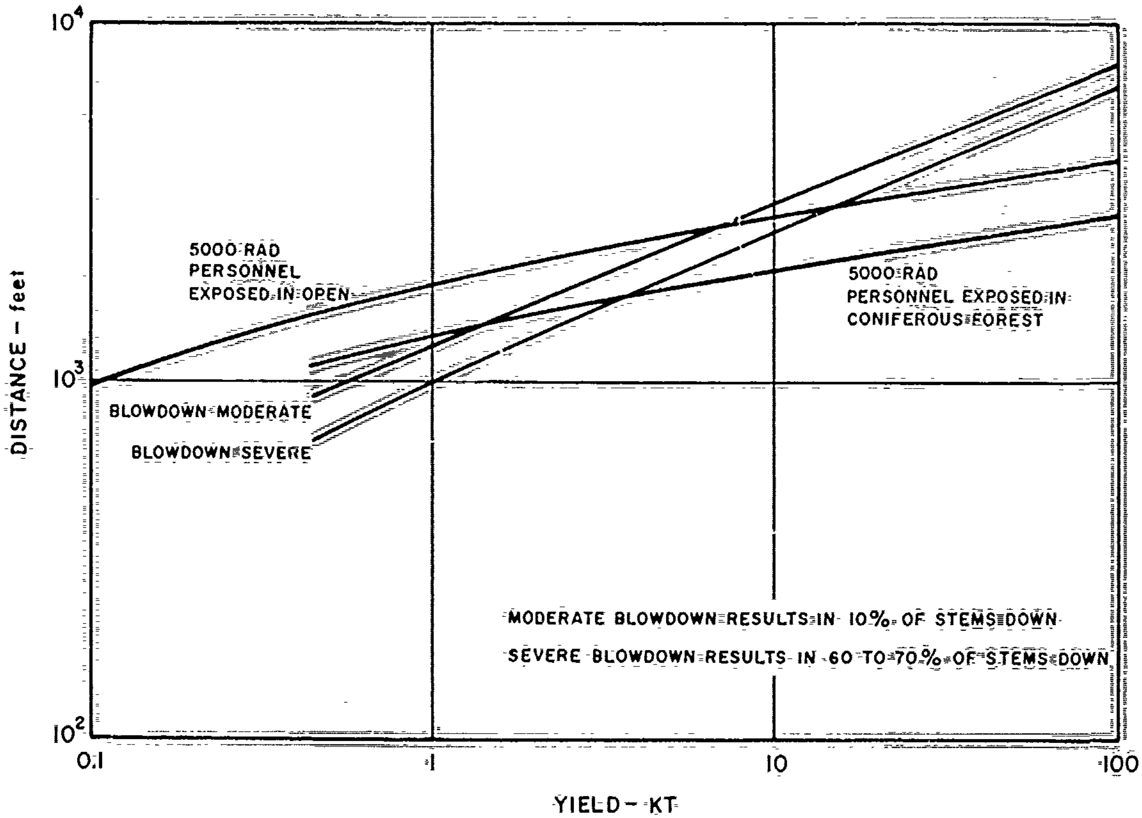
vehicles are likely to have been concealed before the att ck.) The marked map or photo would be delivered to the TOC, where a target analyst would use it in making his post-strike analysis.

Alternatively, a ground survey party could be used. The chief weakness in this would be inability to bound the damage area in a reasonable time. As will be developed later, identifying the outer limits of types of damage is critical to the accuracy of the post-strike analysis. However, if a ground survey party were used, there might be additional indicators such as antenna blow off and damage to vehicles.

Such a correlation can be fairly easily developed using data from DNA EM-1. Figure B-1 shows the radii of severe and moderate tree blowdown* and 5000 rad for personnel in the open and in a forest. Figure B-2 shows similar radii for moderate and severe damage to frame and brick buildings, for 5000 and 150 rad to exposed personnel, and for casualties to persons due to decelerative tumbling caused by the blast. Figure B-3 shows radii for various levels of damage to selected equipment and various radiation doses to personnel.

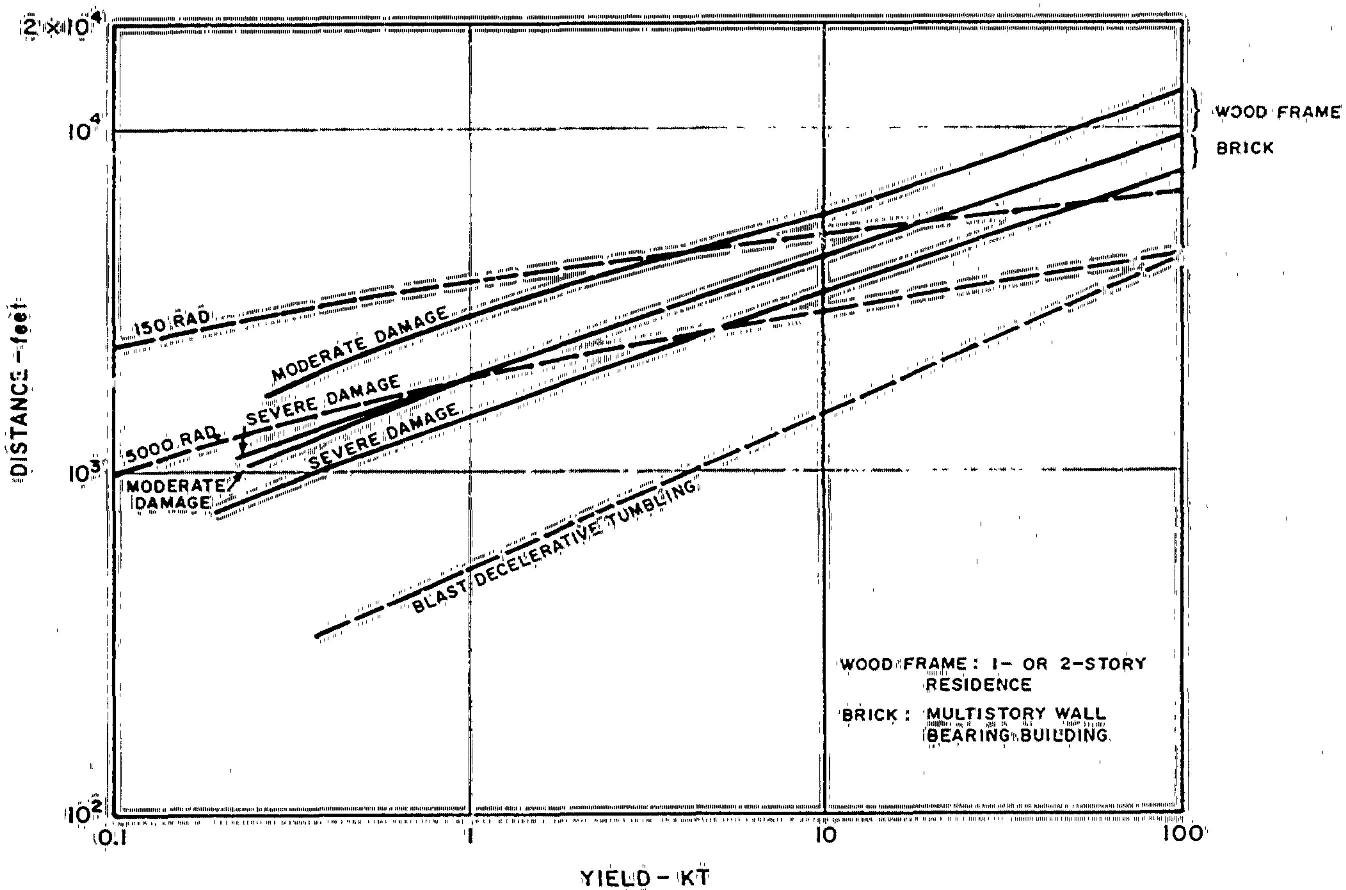
---

*Curves are developed to represent typical relationships that exist between various nuclear effects at various weapon yields. It should be noted that weapon design will alter these relationships. With the exception of unclassified tree blowdown data from FM 101-31-3, "Nuclear Weapons Employment," February 1963,[7] data are based on DNA EM-1.[3]



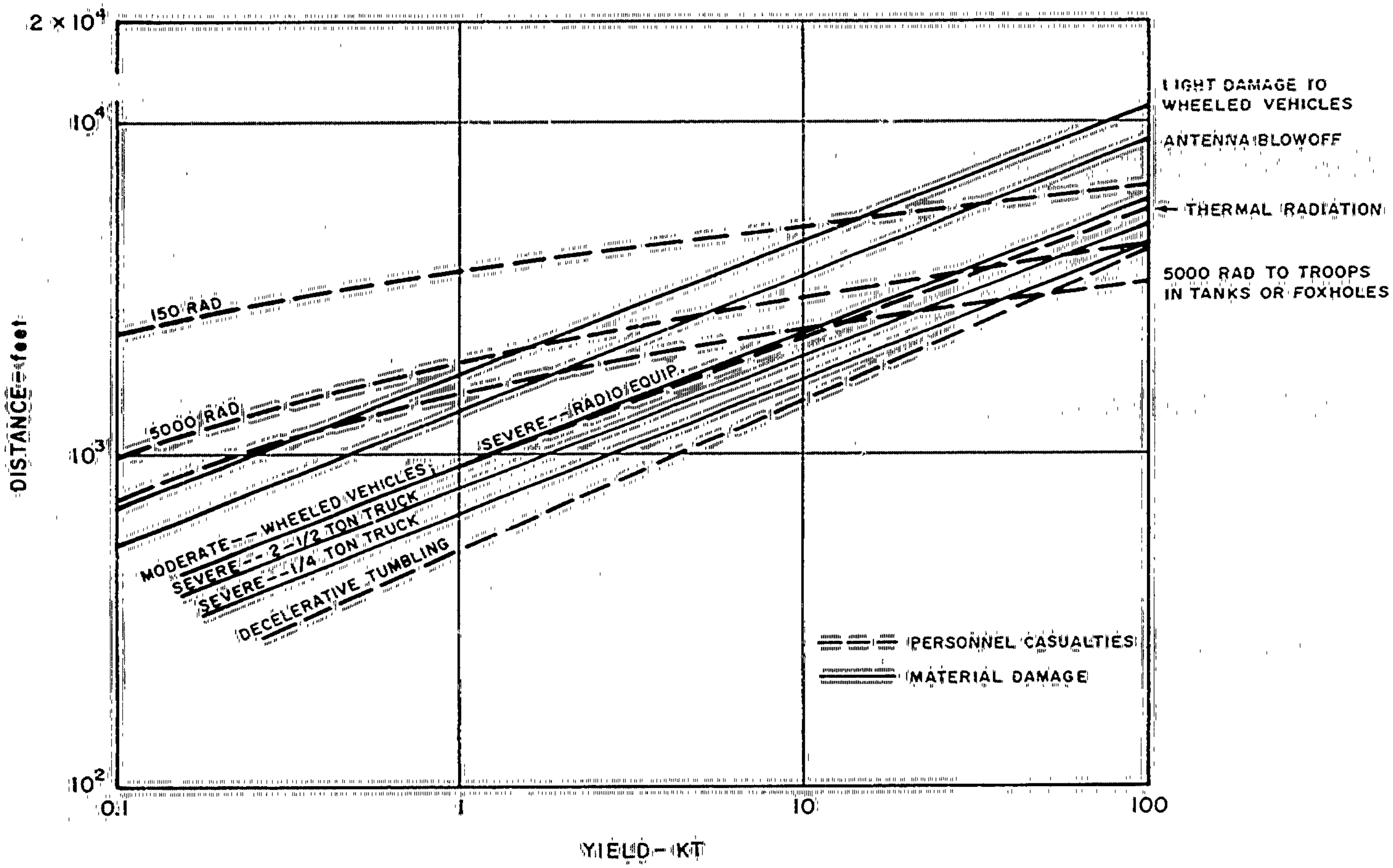
NOTE: CURVES ARE DEVELOPED FOR A REPRESENTATIVE WEAPON DESIGN TO PRESENT TYPICAL RELATIONSHIPS THAT CAN EXIST BETWEEN VARIOUS NUCLEAR EFFECTS

FIGURE B-1. CORRELATION OF FOREST BLOWDOWN WITH INCIDENCE OF CASUALTIES TO EXPOSED PERSONNEL



NOTE: CURVES ARE DEVELOPED FOR A REPRESENTATIVE WEAPON DESIGN TO PRESENT TYPICAL RELATIONSHIPS THAT CAN EXIST BETWEEN VARIOUS NUCLEAR EFFECTS

FIGURE B-2. CORRELATION OF STRUCTURAL DAMAGE WITH INCIDENCE OF CASUALTIES TO EXPOSED PERSONNEL



NOTE: CURVES ARE DEVELOPED FOR A REPRESENTATIVE WEAPON DESIGN TO PRESENT TYPICAL RELATIONSHIPS THAT CAN EXIST BETWEEN VARIOUS NUCLEAR EFFECTS

FIGURE B-3. CORRELATION OF DAMAGE TO EQUIPMENT AND CASUALTY CRITERIA

From the curves in Figures B-1 through B-3 one can extract radii for various effects for selected yields. To establish the desired correlations it is envisaged that cookie cutter type templates would be prepared showing the circles enclosing various types of visible damage and the circles enclosing selected casualty and equipment damage criteria. Figure B-4 presents such templates for a 10-KT and a 1-KT weapon. Note that a family of such templates would be needed, because as yield shrinks blast tends to fall off far more rapidly than radiation; hence, the effect that is the outer circle for one yield will not necessarily be the outer circle for another yield.

To use the templates, the target analyst would take the marked map or photo furnished by the observer and identify the visible effect giving the best coverage, say severe tree blowdown. He would then select the yield template whose outer circle for severe tree blowdown most nearly matched the outer limits of this effect as shown on the map or photo. With the template thus positioned, he would see the various damage criteria circles in their proper position. Then, based on his knowledge of enemy or friendly dispositions in the damage area, he would make his post-strike assessment.

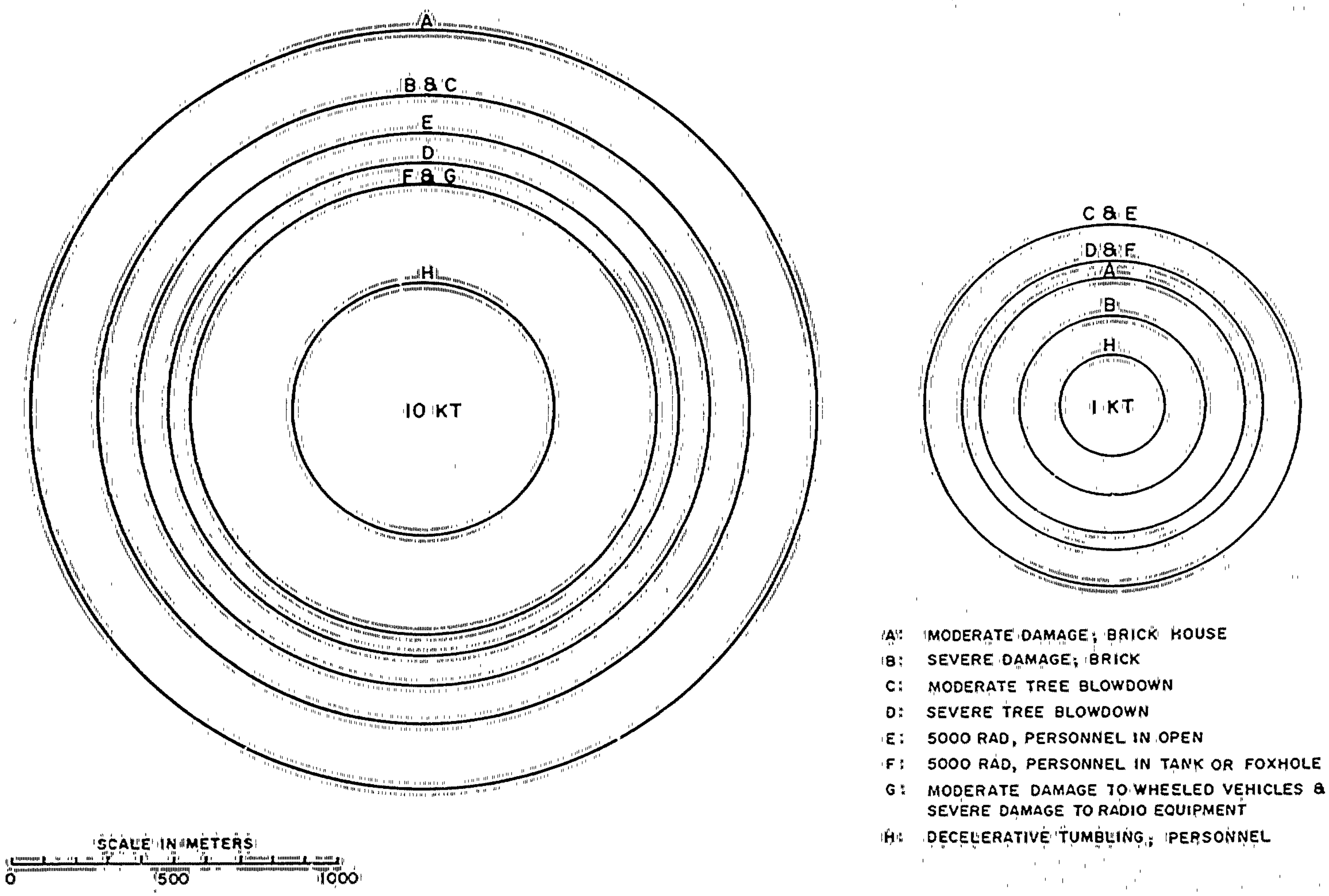


FIGURE B-4. CORRELATIVE DAMAGE TEMPLATES

Appendix C

ESTIMATES OF THE SIGNIFICANCE AND FREQUENCY OF MULTIPLE INJURIES

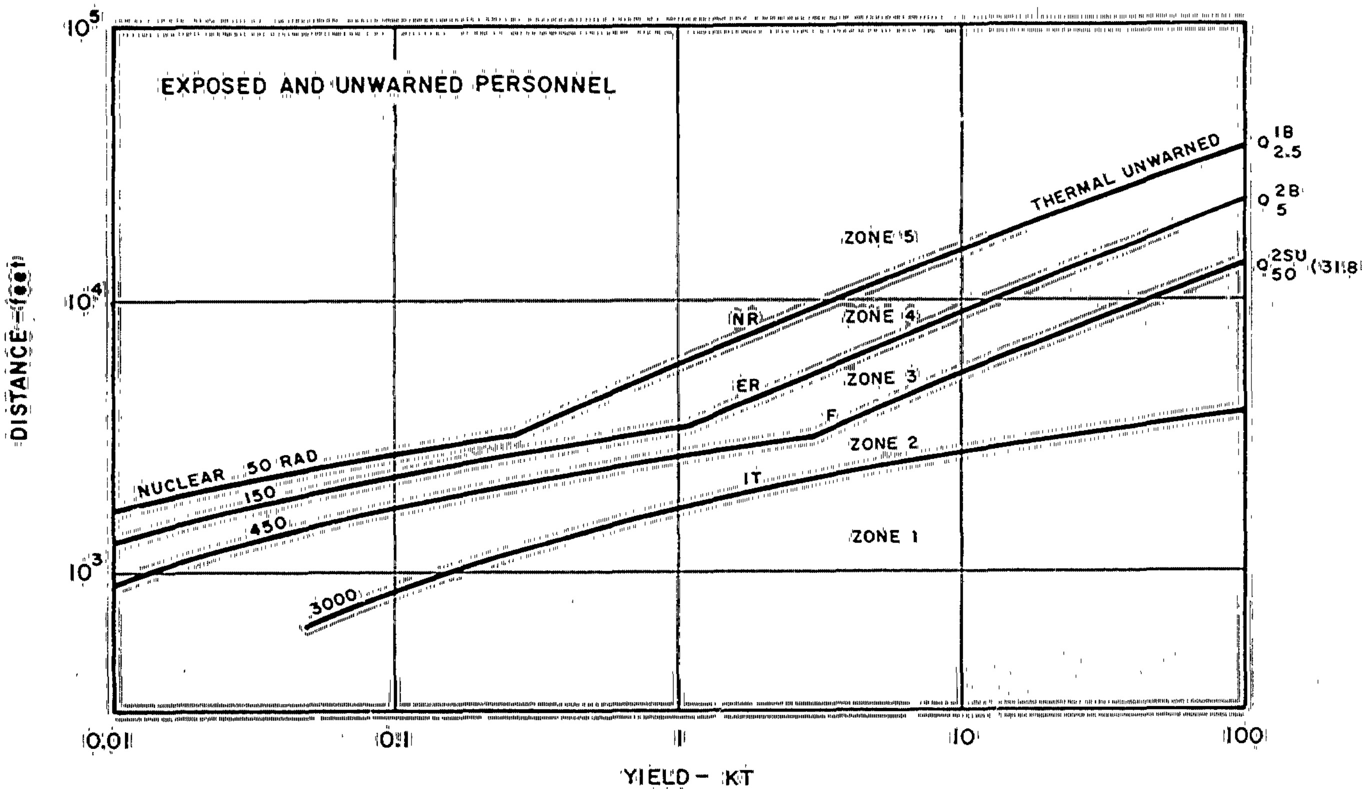
The casualty producing environments resulting from a nuclear explosion tend to overlap to varying degrees, depending on the yield and other factors associated with target and employment conditions. The nature of casualties will vary. A detailed description of fatalities and injuries resulting from a nuclear explosion can show the influence of nuclear radiation, thermal radiation, and blast with its related primary and secondary responses. A continuum of possible human responses from instant fatality close to the detonation to minor injury at distant locations results from single to multiple effects exposures.

Operationally, target analysts tend to think in terms of weapon yields and effects that either produce a militarily significant number of casualties in enemy units or otherwise satisfy an acceptable safety criteria for friendly forces. In the former case, the concept of destroying or neutralizing a specific target is also related to delivery and a statistical assurance of success. Moreover, the prediction of enemy casualties is primarily based on the identification of a single nuclear effect and human response. This approach to the analysis is conservative and fails to suggest the impact on the target of additional injuries and fatalities developed in other response modes and by other nuclear

effects. Although the effects of nuclear weapons can extend much further, in an operational usage troop safety criteria provides a set of operationally acceptable limiting conditions.

Between the casualty and safety criteria are a range of injuries that are not well defined and that, when considered in aggregate, can possibly have a significant influence on military operations. This range of injuries is incurred by people located in various zones, as indicated in Figure C-1. In this figure personnel meeting the casualty criteria are in Zone 1, and those meeting the safety criteria are in Zones 4 and 5. Personnel in the intermediate zones suffer varying degrees of incapacitation. The symbols used in Figure C-1 and in the succeeding figures in this appendix are explained in Table C-1.

Figure C-1 pertains only to persons who were exposed and unwarned at the time of detonation; similar figures could be developed for persons in other postures. For example, for persons in tanks and warned, the distances to which the casualties and risks would extend would be reduced, nuclear radiation would remain the significant nuclear effect for low yields, but blast effects would replace thermal effects for the higher yields. Figure C-1 illustrates the type of information needed; a set of special curves could be developed for other postures. The curves present typical relationships; however, changes in weapon design can change these relationships. Moreover, the nature of military targets is such that the population may be best represented by a combination of several postures.



NOTES: SEE TABLE C-1 FOR NOTATIONS

CURVES ARE DEVELOPED FOR A REPRESENTATIVE WEAPON DESIGN TO PRESENT TYPICAL RELATIONSHIPS THAT CAN EXIST BETWEEN VARIOUS NUCLEAR EFFECTS

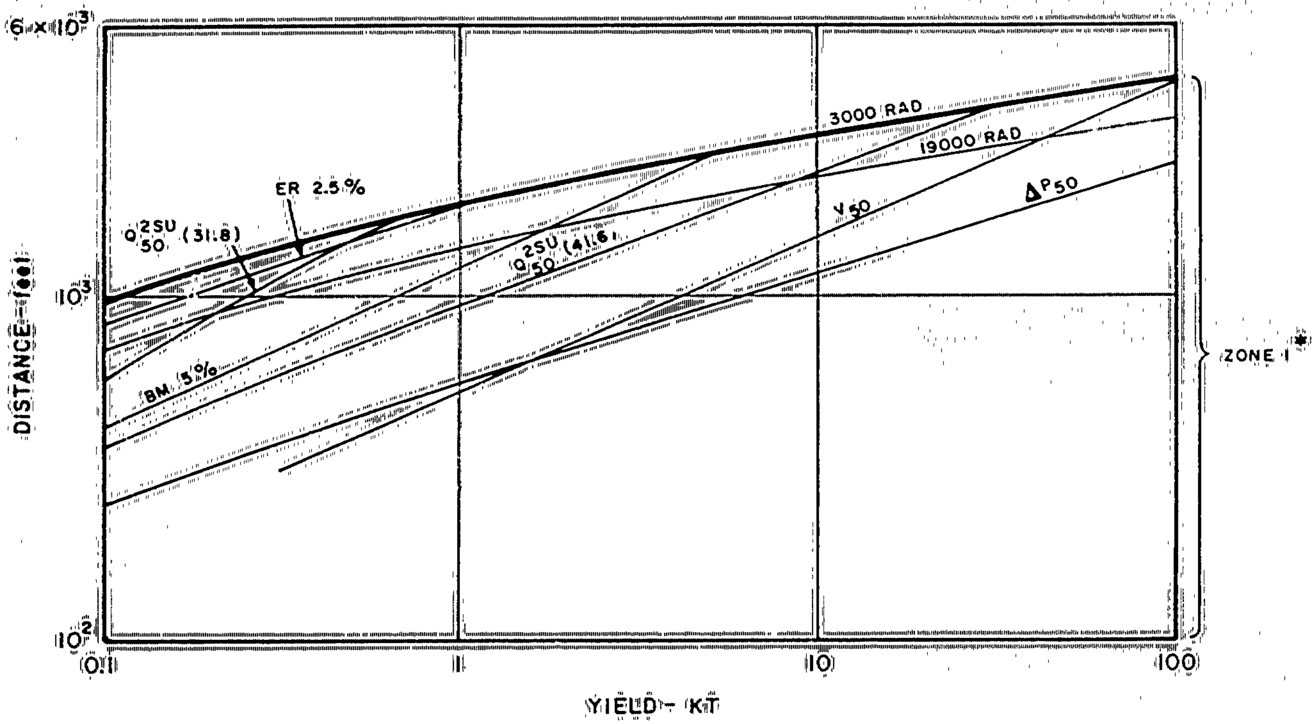
FIGURE C-1. SAFETY AND CASUALTY RADII FOR VARIOUS YIELDS

TABLE C-1. LEGEND KEY FOR FIGURES IN APPENDIX C

Thermal effects		
$Q^{1B}_{2.5}$	2.5% incidence of 1st degree burns	
Q^{2B}_{5}	5% incidence of 2nd degree burns	
Q^{2SU}_{50} (31.8)	50% incidence of 2nd degree burns to 31.8% of body area under summer uniforms	
Q^{2SU}_{50} (41.6)	50% incidence of 2nd degree burns to 41.6% of body area under summer uniforms	
Blast effects		
ER 2.5%	2.5% incidence of eardrum rupture	
BM 5%	5% incidence of casualties from missiles	
V_{50}	50% incidence of casualties from decelerative tumbling at 76 ft/s velocity	
ΔP_{50}	50% incidence of casualties from lung collapse due to overpressure at 43 psi	
Zone boundaries		
NR	negligible risk	50 rad, $Q^{1B}_{2.5}$
ER	emergency risk	150 rad, Q^{2B}_{5}
F	fatalities	450 rad, Q^{2SU}_{50} (31.8)
IT	immediate transient incapacitation	3000 rad, ΔP_{50}

Response may be generalized. Figure C-1 suggests five zones for the investigation of personnel casualties. As stated above, within Zone 1 are personnel who have been exposed to at least the operational casualty level. Personnel in all other zones do not meet this criteria; however, Zone 2 personnel are expected to be fatalities eventually (within 90 days). The people within Zone 3 do not become fatalities generally, but will be seriously injured. The population in Zone 4 is based on emergency risk criteria. These people will receive a few serious injuries, but under present nuclear operations policy they should remain militarily effective. The people in Zone 5 are exterior to the area of negligible risk; they should experience only minor injuries and should continue to be militarily effective.

A pattern of responses to the nuclear effects within Zone 1 is presented in greater detail in Figure C-2. Although the zone is structured on the desired military casualty criteria, other casualties are possible. The other fatality producing responses--decelerative tumbling and second degree burns on greater than 31.8% of the body for example--will occur but are subordinated to the nuclear radiation response. Yields below 1 KT will have a low incidence of injury other than nuclear radiation. However, at yields greater than 10 KT, blast and thermal effects contribute to the casualty stress in the zone. Of interest to planners will be the degree to which the blast and thermal injuries will occur and to what extent this will be effective in further debilitating the immediate transient incapacitation response from nuclear radiation.



* ZONE I HAS BEEN DEFINED FOR THIS STUDY ON THE BASIS OF THE TARGET POPULATION RECEIVING AT LEAST THE OBJECTIVE CASUALTY PRODUCING ENVIRONMENT OF 3000 RAD

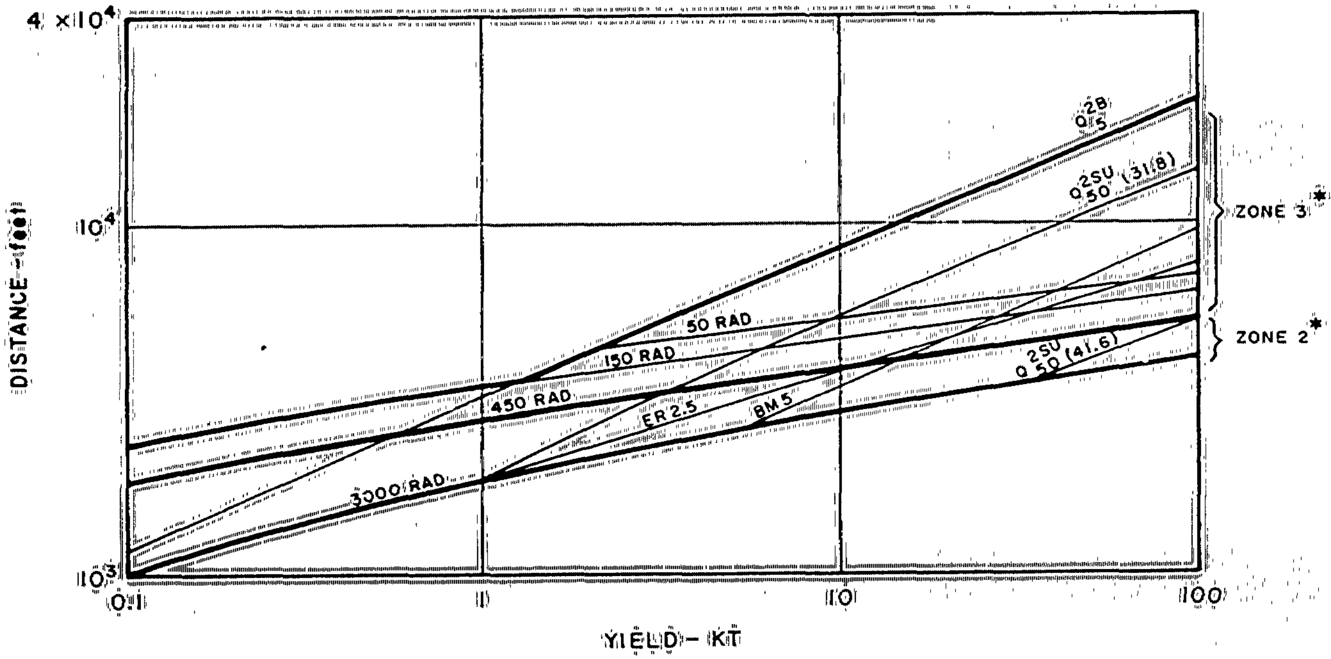
NOTES: SEE TABLE C-I FOR NOTATIONS

CURVES ARE DEVELOPED FOR A REPRESENTATIVE WEAPON DESIGN TO PRESENT TYPICAL RELATIONSHIPS THAT CAN EXIST BETWEEN VARIOUS NUCLEAR EFFECTS

FIGURE C-2. DETAILS OF CASUALTIES IN ZONE ONE

Of equal interest is the population response in Zone 2, which is depicted in Figure C-3. Here fatal nuclear radiation levels will have been received. Typically, however, target analysts do not consider this population as casualties in planning current operations even though incapacitation in the long term will occur. In this zone the population will also have a reasonably high incidence of sublethal blast and thermal injuries. Multiple injuries will occur; however, research to date has not been able to satisfactorily quantify these casualty modes. Response data in DNA EM-1 suggests that nuclear and thermal radiation casualties will be commonplace for yields over 1 KT and that blast injuries will also occur for yields over 10 KT. Some evidence from Hiroshima, to be developed shortly, also suggests that multiple injuries will be a common occurrence; however, the effects on military performance and the acceleration of the incapacitation process are not known. Information on the nature of injuries, and human response to one or multiple injuries, can contribute to a better understanding of operational capabilites of the nuclear weapons.

Survivors with nuclear radiation injuries in Zone 3 will have been exposed to a radiation dose between 150 and 450 rad. Many will also exhibit thermal injuries at yields greater than 1 KT. Thermal and blast injuries or thermal injuries alone can also be encountered at yields greater than 10 KT. The severity and extent of these injuries will determine hospital loads, replacement policies, recuperation time and level of combat activity among the surviving population. Zone 3 shares with Zone 2 the uncertainty of human response to sublethal and multiple nuclear injuries.



* ZONES 2 AND 3 HAVE BEEN DEFINED FOR THIS STUDY ON THE BASIS OF THE TARGET POPULATION BEING FATALLY INJURED FOR ZONE 2 OR SERIOUSLY INJURED FOR ZONE 3

NOTES: SEE TABLE C-1 FOR NOTATIONS

CURVES ARE DEVELOPED FOR A REPRESENTATIVE WEAPON DESIGN TO PRESENT TYPICAL RELATIONSHIPS THAT CAN EXIST BETWEEN VARIOUS NUCLEAR EFFECTS.

FIGURE C-3. DETAILS OF CASUALTIES IN ZONES 2 AND 3

In Zone 4, between negligible and emergency risk levels, incidence of militarily significant injuries will be low. The population is expected to be combat effective in spite of nuclear exposure. Monitoring of this population after an attack is warranted for possible occurrence of significant departures from the normal safe response. Incidence of nuisance or debilitating injuries that might have been prevented through training or procedures should be reviewed for possible corrective action. Selected follow-up should be maintained for detection of possible delayed or long-term responses.

Many of the comments relevant to Zone 4 pertain to Zone 5. This population should be combat ready, with not more than 2.5% of them stressed by nuisance level injury. Confirmation of this expectation is warranted for both the short and long term. Detection of an "Achilles' heel" and prevention of needless casualties through training and procedures should be pursued.

1. Cross-Section Data at 12.5 KT

Incidence rates of fatalities and injuries should be further developed for all zones. Hiroshima casualty data provides an insight to the frequency of occurrence of various casualties. In using these data it should be remembered that there are several significant differences between the data and expectations for theater nuclear warfare situations. At Hiroshima, personnel were untrained and unwarned, height of burst was optimized for blast damage in the low pressure regime, and the nuclear radiation was less intense than that anticipated from modern tactical weapons.

As shown in Figure C-4, fatalities exhibit a 50% occurrence at approximately 450 rads.* Fatalities as used in these data are based on nonsurviving injured personnel. This includes both immediate fatalities and all persons who succumbed within 90 days of the attack. This definition, therefore, corresponds to the aggregation of casualties in Zone 1 and Zone 2 of Figure C-1.

Personnel unwarned and exposed are vulnerable to a high incidence of thermal injury. Segmentation of data into severe blast, severe nuclear radiation, and severe thermal injuries provides some additional correlation to the nature and frequency of injuries among the surviving population. Table C-2 shows such a segmentation. The Hiroshima cross-section data provides added insight into the nature of injuries among surviving personnel. Figure C-5 considers surviving injured personnel. The three classifications of injury, nuclear, blast, and thermal, have been further segmented to indicate severe injuries as a subclass for each. The occurrence of multiple injuries is prevalent, as is evidenced by the fact that the sum of individual injuries in most cases is greater than the total. Intuition confirms this, for if the population is in an exposed posture, all three nuclear effects are potential casualty producing mechanisms.

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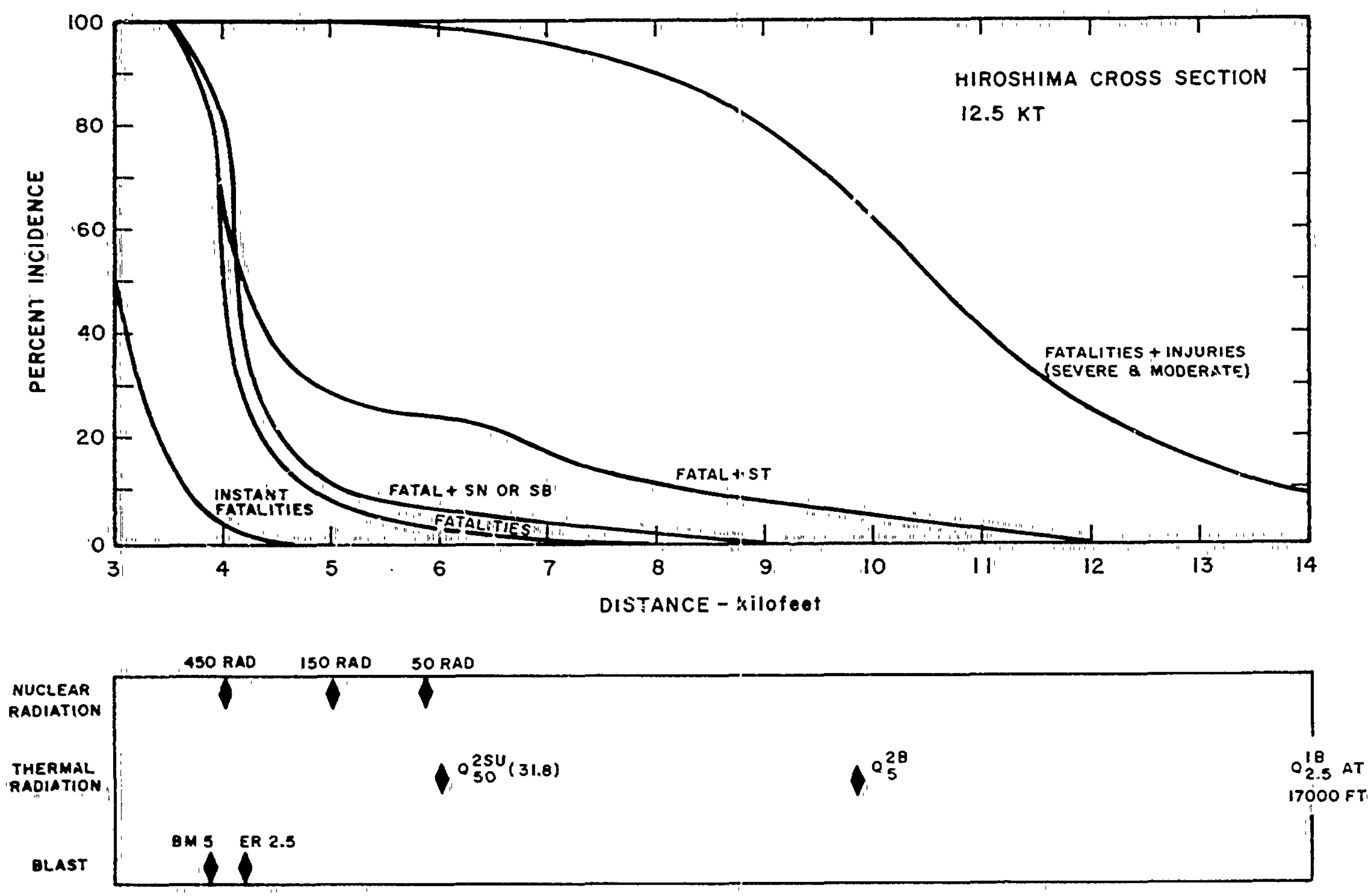
*Because of differences in weapon design and height of burst, radiation-dose distances for Hiroshima cannot be directly correlated with the information given in Appendices A and B. Results and conclusions are of a general nature only.



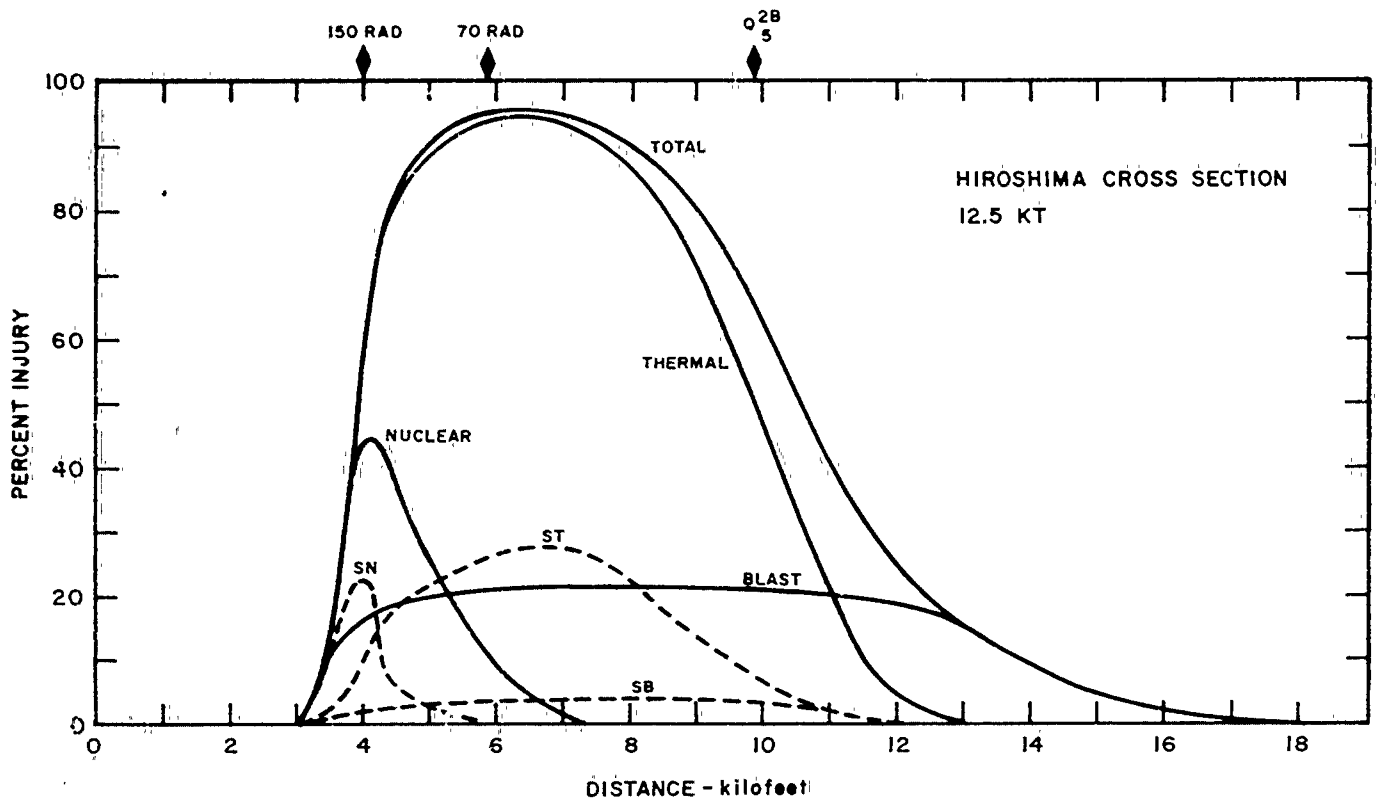
SN = SEVERE NUCLEAR RADIATION INJURY
SB = SEVERE BLAST INJURY
ST = SEVERE THERMAL RADIATION INJURY

NOTE: SEE TABLE C-1 FOR NOTATIONS

FIGURE C-4. INCIDENCE OF INJURIES AND FATALITIES TO EXPOSED PERSONNEL

TABLE C-2. SEGMENTATION OF HIROSHIMA INJURY DATA

Type of injury	Moderate	Severe
Radiation	Epilation and white blood count (WBC) 2000 to 4000.	(1) WBC less than 2000 or (2) WBC 2000 to 4000 and epilation with any two of: • Hemorrhagic manifestation • Oropharyngeal inflammation • Nausea and/or vomiting on day of exposure.
Blast or mechanical	(1) Single laceration, cut, abrasion, contusion, or the like, plus (2) Simple fracture, not of a long bone.	(1) Multiple lacerations, cuts, abrasions, and contusions, plus (2) Fracture of one or more long bones, simple or compound; compound fracture of other bones; fracture of skull; fracture of spine.
Thermal	Less than 10% of body area with 2nd degree burns and less than 2% of body area with 3rd degree burns.	More than 10% of body area with 2nd degree burns.



SN = SEVERE NUCLEAR RADIATION INJURY
ST = SEVERE THERMAL RADIATION INJURY
SB = SEVERE BLAST INJURY

FIGURE C– 5. DISTRIBUTION OF INJURIES AMONG SURVIVING EXPOSED PERSONNEL

The occurrence of various types of multiple injury was tabulated from an analysis of the Hiroshima data.[8] The inability of the analysis to account, in Table C-3, for a significant fraction of the injuries at certain ranges points up the tentative nature of the analysis. The most common occurrence of multiple injuries to persons in the open was thermal and nuclear radiation injuries. Bear in mind that injured, as used here, does not include eventual fatalities. Lack of a significant occurrence of multiple injuries including severe blast appears to result from the greate atality rate among this group because of the additional thermal or nuclear radiation exposure.

2. Influence of Protection Posture

Data is also available from the Hiroshima cross section for injuries and fatalities to various segments of the population found within a protective structure. The most protective posture exhibited in the data is for seismic reinforced concrete buildings. This protection approximates the blast protection of military tanks. If allowances in the Hiroshima data are made for differences in nuclear radiation sources and transmission factors, the effects of nuclear radiation should be comparable to the ase of modern weapons and the protection afforded by tanks. The influence of this protective posture is to decrease the incidence of casualties at a given distance, as shown by the comparison of Figures C-4 and C-6. Blast and nuclear radiation become the dominant casualty producing mechanism and as shown in Table C-4, multiple injuries occur as a combination of moderate blast injuries with

TABLE C-3. OCCURRENCE OF COMBINED INJURY FROM HIROSHIMA DATA--EXPOSED (12.5 KT)

Range (feet)	Any injury*	Moderate blast	Moderate thermal	Severe thermal	Moderate thermal and moderate nuclear	Moderate thermal and severe nuclear	Unaccounted
	Percentage of exposed and unwarned population injured						
3,500	0%	0%	0%	0%	0%	0%	0%
4,000	35	0	9	5	7	3	11
4,500	81	1	22	11	10	3	34
5,000	90	1	30	19	11	3	26
5,500	94	2	34	25	9	2	22
6,000	96	2	37	30	6	0	21
6,500	96	3	39	36	4	--	14
7,000	95	3	39	41	1	--	11
7,500	93	4	39	42	0	--	8
8,000	90	4	38	40	--	--	8
9,000	80	6	35	30	--	--	8
10,000	63	8	31	17	--	--	7
12,000	24	8	14	0	--	--	2
14,000	9	9	0	--	--	--	0
16,000	2	2	--	--	--	--	--
18,000	0	0	--	--	--	--	--

*Injured persons exclude fatalities that occurred within the first 90 days after exposure.

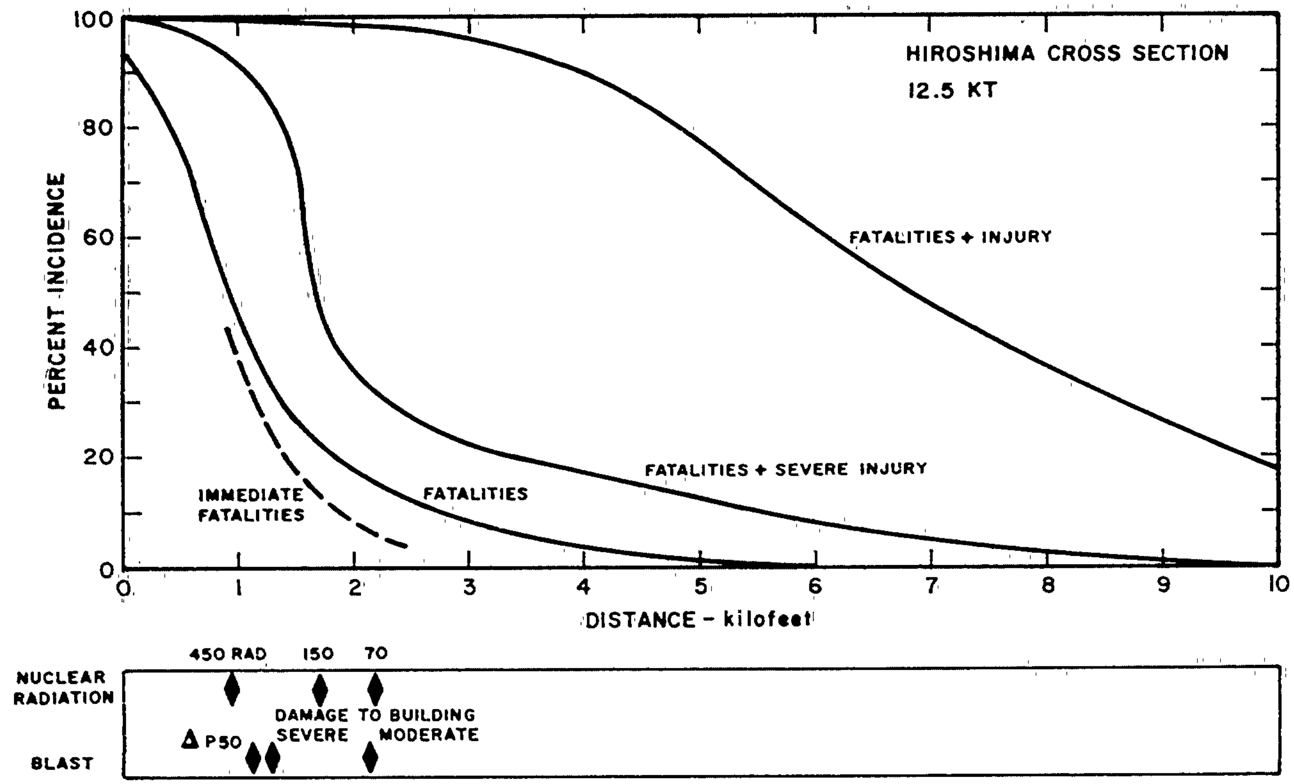


FIGURE C-6. INCIDENCE OF INJURIES AND FATALITIES AMONG PERSONNEL INSIDE OF SEISMIC REINFORCED BUILDINGS

TABLE C-4. OCCURRENCE OF COMBINED INJURY FROM HIROSHIMA DATA--REINFORCED STRUCTURES (12.5 KT)

Range (feet)	Percentage of population injured in seismic reinforced structures					
	Any injury*	Moderate blast	Severe blast	Moderate blast and moderate nuclear	Moderate blast and severe nuclear	Unaccounted
0	6%	0%	0%	3%	2%	1%
500	20	1	0	6	5	8
1,000	50	6	1	12	9	22
1,500	72	16	2	12	10	32
2,000	82	30	5	9	8	30
2,500	87	48	8	6	5	20
3,000	89	60	12	2	2	13
3,500	89	64	15	1	1	8
4,000	86	64	17	0	0	7
5,000	76	60	15	--	--	2
6,000	62	54	6	--	--	0
7,000	48	47	1	--	--	--
8,000	36	36	0	--	--	--
10,000	17	17	--	--	--	--

*Injured persons exclude fatalities that occurred within the first 90 days after exposure.

either moderate or severe levels of nuclear injury. The absence of multiple injuries that include severe blast injuries suggests that, when severe blast is associated with either a moderate or severe nuclear radiation injury, the results are fatal. This latter conclusion is supported by an observed high first day fatality rate of 70% for the total population.

3. Conclusions

The nature and occurrence of multiple exposures to nuclear effects is sufficient to warrant a high priority to the collection of these data in the event of nuclear combat. Two levels of interest are specified. First, for operationally defined casualties there is a need to understand the occurrence of various casualties and the synergistic effects of two or more injuries. This will be useful to understanding target defeat criteria and to a possible redefinition of nuclear targeting procedures.

Second, it is clear that between the military sure kill and sure safe criteria there is a wide range of possible injuries. These casualties will influence the utility of the concept of bonus damage. Moreover, with respect to friendly forces, a better understanding of these injuries will assist in an understanding of short-term combat capabilities, unit replacement policies, and hospital loads.

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